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CHEMICAL SECTION.

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Stability Tests for Nitro-Cellulose and Nitro-Cellulose Powders.

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Stability tests for explosives are little known outside of the manufacturers' and the Government laboratories. The object of this article is to present a review of the more important and most-used tests, especially those used at the Frankford Arsenal.

"Stability tests," sometimes also called "heat tests," are applied to explosives to determine their stability or keeping qualities. By the manufacturer these tests are also used during the process of manufacture to determine if the product has been sufficiently purified.

*The Abel Test.**—This is the oldest test for stability and one which is still used extensively, especially in England.

* *Transactions Royal Society*, 1866, 269.

In this test the explosive is heated to temperatures varying from 65·5° to 100° C., and the time noted which is required to produce a discoloration on a test-paper of potassium-iodide starch.

At this laboratory this test is conducted as follows:* 1·3 gram of the sample (air-dried) is placed in a test-tube 6 inches long by ½ inch wide. The test-tube is then closed by a cork carrying a glass rod, the latter having a hook of platinum wire fused in at the lower end. On this hook there is suspended a strip of the KI-starch test-paper moistened to one-half its length with a 50 per cent. glycerin solution. (*Fig. 1.* Test-tube shown one-half actual size.) The position of the test-paper in the test-tube is so adjusted that the line dividing the dry and wet portions of the paper is on a level with the lower edge of the film of moisture expelled from the explosive and deposited on the inside of the test-tube. The tube is immersed in a bath, the temperature of which is regulated to 65·5° C. (± 1°) for nitro-cellulose, and to 100° C. (± 1) for smokeless powders (nitro-cellulose powders). The arrangement of this bath is shown in *Fig 1.* Into an open water-bath there is placed a copper vessel containing water or glycerin, having a cover consisting of three perforated and parallel disks about 1 inch apart. The holes in the upper and middle disk are just large enough to admit the test-tubes, while those in the lower disk are smaller. This arrangement serves to hold the tubes all at the same level and in a vertical position, and is a decided improvement over the old form of apparatus usually shown in connection with this test.

When the bath has reached the required temperature the tubes with the sample are immersed and the test begins at this moment; it ends at the appearance of a brown line on the test-paper at the juncture of the dry and wet portions. For a good nitro-cellulose this discoloration must not take place in less than forty minutes (at 65·5° C.), and not less than ten minutes (at 100° C.) for a good nitro-cellulose powder. Powders containing nitroglycerin should

* Standard Methods of Chemical Tests of Nitro-Cellulose, etc., prescribed by Ordnance Department, May 1, 1902.

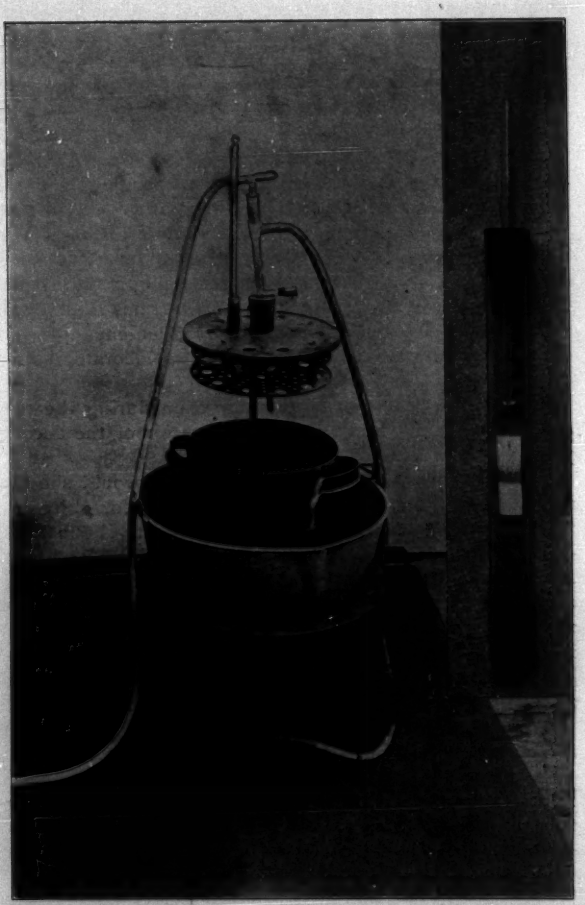

FIG. 1.—Stability tests of nitro-cellulose and nitro-cellulose powders. Potassium iodide and starch test.

stand the test for twenty minutes at 65·5° C. This discoloration of the potassium-iodide starch paper is due to the action of free iodine on the starch, the iodine being liberated from the KI by impurities, or products of decomposition* volatilized from the sample.

This test as described, or with some slight modification, especially in the temperature employed, is more extensively used than any other. However, it is of most value to the manufacturer, since by careful application of the test he can determine whether nitro-cellulose or nitroglycerin is perfectly free from traces of acid. The test could be called a "purity test" more appropriately than a "stability test." When applied to finished products this test has many weak points which have been pointed out by other chemists and corroborated by results obtained in this laboratory after years of use.

(1) It shows in cases of decomposition during the test only the beginning and not the continuation of the decomposition.†

(2) Traces of unstable nitro-compounds would show a nitro-cellulose, or a powder in which they are found by this test to be bad; yet these traces of comparatively unstable compounds might not cause a decomposition of the explosive if kept under ordinary conditions. And, considering that there is no indication as to the effect of these traces of unstable compounds, this test does not indicate the keeping qualities of the explosive.

(3) In case of a nitro-cellulose powder, this test may be affected by traces of solvents left in the powder.

(4) The weakest point of this test lies in the fact that it can be masked by a number of substances which are sometimes added to the explosive for that purpose. Mercuric chloride, or mercury salts, are most frequently used for this purpose.‡

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* Principally nitrogen oxides and acids.

† Will: Mittheilungen a.d. Centralstelle f. wissenschaft. Untersuchungen.

‡ "The presence, in the sample, of mercuric chloride, or alkali, or any other substance which might in any way mask or interfere with the heat test, will be sufficient to cause its rejection." Stand. Meth. of Chem: Tests. Prescribed by Ord. Dpt. U. S. Army, p. 3.

According to Thomas,* $HgCl_2$ is reduced to Hg which unites with the oxides of nitrogen, preventing volatilization of the latter, and consequently retards the reaction on the test-paper. A test-paper which shows the reaction is readily bleached when exposed to vapors of mercury. Samples of nitro-cellulose have been received at this laboratory, which contained metallic mercury which had been added as such or had been reduced from a mercury salt.

Amines have been added to nitro-cellulose and powders in order to mask or lengthen the stability test.† Amines react with nitrous fumes as follows:

$$R \cdot NH_2 + HONO = R(OH) + N_2 + H_2O.$$

Small quantities of alkalies or carbonates are sometimes added to neutralize remaining traces of nitrating acids, and also to combine with nitrous fumes resulting from decomposition.‡

Other substances used to mask the stability test are§ acetic ether, acetone, oils, vaseline, aniline.

(5) Variations in length of stability indicated by this test may be caused by variations in the condition of the sample to be tested; the size of the grains or pieces, whether cut or rasped:‖ whether freshly prepared for the test, or exposed to the air for varying lengths of time, which would allow the escape of volatile substances which might indicate a bad stability if not allowed to escape. Moisture-content of sample affects stability time.

(6) Difference in test-papers gives results which vary

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* *Zeit. f. Ang. Ch.*, 1898, 1027.

† *Zeit. Ang. Ch.*, 1899, 705.

‡ The value of the presence of alkalies or carbonates in nitro-cellulose to increase stability by neutralizing acids is a disputed point. Guttmann (*Zeit. Ang. Ch.*, 1897, 233) discourages this practice, contending that the real decomposition of a nitro-cellulose soon develops more than enough acid to be neutralized by the small amount of added alkali. Under some conditions, alkalies decompose or saponify nitro-compounds.

§ *Zeit. Ang. Ch.*, 1897, 233.

‖ *Zeit. Ang. Ch.*, 1897, 265. Guttmann found that it required eight and one-half minutes to heat ground cordite from 12° to 69½° C.

greatly and are in no way comparative.* The age of the test-paper also affects its sensitiveness.†

(7) The personal equation of the operator enters as a factor in causing variations. It is no easy matter to decide just when there is "the first appearance of the brown line" on the test-paper, or just when the line is of the same intensity as a standard.

From what has been said, it must be apparent that this test, the potassium-iodide starch test, has too many weak points to make it a reliable one for determining the stability of nitro-cellulose or powders. The test is made on all nitro-cellulose and powders received at this laboratory, the same operator making all the tests under as nearly uniform conditions as possible. However, no explosive is condemned on the results of this test alone.

THE GUTTMANN TEST.‡

This is the Abel test modified by substituting a test-paper of diphenylamin for the potassium-iodide starch paper. Guttman claims for it the following advantages over the Abel test:

(1) Not as sensitive.

(2) Test-paper more easily prepared.

(3) Masking substances do not interfere as much.

He had reviewed the literature and tried nearly all the reagents which had been used for detecting nitrous acid for the last forty years, and finally selected diphenylamin as the one which is best adapted for his modification of the Abel test.

The apparatus used is the same as given in the books for the Abel test. Temperature 70° C. instead of 65·5° C.

The test-papers are made by moistening the upper half of a strip of clean filter paper with the following solution:

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* The test-papers used by the Ordnance Department U. S. A. are made in quantity by Eimer & Amend, New York, according to specifications, thereby insuring greater uniformity than if made at different laboratories in small quantities. Manufacturers who have contracts with the Ordnance Department are supplied with these papers.

† *Journ. Soc. Ch. Ind.*, 1901, 8.

‡ *Zeit. Ang. Ch.*, 1897, 233. *Journ. Soc. Ch. Ind.*, 1897, 283.

Diphenylamin	0·1 gram.
Sulfuric acid	10 c.c.
Water	42 c.c.
Pure glycerin	50 c.c.

This solution must be kept in the dark.

The effect of nitrous fumes on this test-paper is to turn it from colorless to a greenish yellow, after which a blue color should follow in a few seconds.

Thomas says* the diphenylamin-test is unsatisfactory. It may be masked by adding diphenylamin to the sample under examination, in which case the paper will turn yellow, but not blue. Guttmann himself admits that the blue color sometimes fails to appear; in such case he repeats the test. He also says† that the test is vitiated by moisture in the sample, causing a dilution of the reagent on the test-paper. Thomas' claim that diphenylamin test-paper gives no sharp reaction (*i. e.*, a decided blue color in a short time after the greenish yellow) is corroborated by other chemists.

The Guttmann test was tried at this laboratory but gave unfatisfactory results. Thomas, Aspinwall,‡ Spica,§ find sufficient objections, after trial, to discard it. Major Nathan says‖ that the Guttmann test fails when testing volatile explosives such as nitroglycerin. Nitroglycerin is decomposed by the sulfuric acid on the test-paper.

The Zinc-iodide Starch Test is a modification of the Abel test, using zinc-iodide instead of potassium-iodide and a temperature of 80°. The reasons for using zinc-iodide seem to be its greater sensitiveness ¶ and its action as a preservative of the test-paper. The increase in sensitiveness is in no way an improvement of the Abel test, and results obtained at this laboratory show that the modification is not more

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* *Zeit. Ang. Ch.*, 1898, 1027.

† *Zeit. Ang. Ch.*, 1898, 1103.

‡ *Journ. Soc. Ch. Ind.*, May 31, 1902.

§ Spica: Rivista, Ang., 1899.

‖ *Journ. Soc. Ch. Ind.*, 1901, 10.

¶ Guttmann, in Lunge: "*Ch. Tech. Untersuchungsmeth.*," II, p. 492, says: Zinc-iodine test-paper is about one-third more sensitive than potassium-iodide paper.

reliable than the original. The requirements for stability by this test vary greatly. Using 80° C.:

Prussia (official test) requires for					nitro-cellulose	25 min.
Holland	"	"	"	"	"	20 "
"	"	"	"	"	N. C. powder	10 "
"	"	"	"	"	nitroglyc. powder	10 "
Denmark	"	"	"	"	nitro-cellulose, before addition of $HgCl_2$	10 "
"	"	"	"		after addition of $HgCl_2$	60 "
Troisdorff test requires for					N. C. powder	80 "

This test has all the weak points mentioned under the Abel test.

THE HESS TEST.

As early as 1879 Hess realized that in testing explosives for stability it is not sufficient to know when decomposition begins, as indicated by the Abel test and its modifications, but it is also necessary to know how decomposition proceeds. One of the first attempts to follow for some time the decomposition of an explosive is described by Hess.* He heated nitro-cellulose to 70° C. in a tube and, by means of a current of air, carried the volatile products of decomposition into a dilute potassium-iodide starch solution. He made five observations or readings—four colorimetric readings of the potassium-iodide starch solution, and the time required for exploding the substance.

The weak points of this test are that, like the Abel test, it is far too sensitive and may show decompositions which in reality do not indicate instability of the powder. The test is also subject to interference by masking substances as described under the Able test.

THE HOITSEMA TEST.†

Another test, in which an attempt is made to show the progress as well as the beginning of decomposition, is described by Hoitsema. He heated nitro-cellulose for fifteen minutes at a constant temperature, and then, by

* "Mitth. ü. Gegenstände d. Artill. u. Geniewesens," 1879, 345. *Dingler Polytech. Journ.*, 234, 43.

† *Zeit. Ang. Ch.*, 1899, 705.

means of a current of carbon dioxide, passed the products of decomposition through glass-wool moistened with Guttmann's diphenylamin solution (mentioned under Guttmann's Test). This operation was repeated, lowering the temperature 10° each time, until a temperature was found at which no decomposition took place, *i. e.*, at which no products of decomposition were formed which gave a color-reaction with the diphenylamin.

Here, as in the Hess Test, the test is too sensitive, and may be masked as mentioned under the Guttmann Test.

THE EXPLOSION TEST.

This belongs to a number of tests where the temperatures employed are higher, the decomposition greater, and the observations of the decomposition are made on less sensitive indicators than in the tests so far described. For the explosion test, a small sample (usually 0·1 gram) of the explosive is placed in a strong test-tube, which is then corked and placed into an oil bath which is heated gradually until the sample explodes. The temperature, below which nitro-cellulose and powders must not explode in order to be considered stable, varies in different places.

	Degrees C.
Denmark (official) nitro-cellulose	180
Holland (official) nitro-cellulose powder	170
Troisdorff laboratory, small-arms powder	178
" " cannon powder	173
Westpf. Anhalt., Spreng. Act. Gesell. N. C. powder	178
" " " " " N. Glyc. powder	170

The explosion test is made at this laboratory on all nitro-celluloses and powders. The apparatus used (*Fig. 2*) consists of a paraffine bath provided with a thermometer, and a stirring apparatus operated by a small water motor. The bath has a cover with six holes for the explosion tubes (*Fig. 2*, tube shown one-half actual size). Into these tubes there is placed 0·1 gram of the sample, then lightly corked and put into the bath at 100° C. The bath is now stirred and heated at such a rate that the temperature rises 5° per minute. The temperature is noted when the sample explodes.

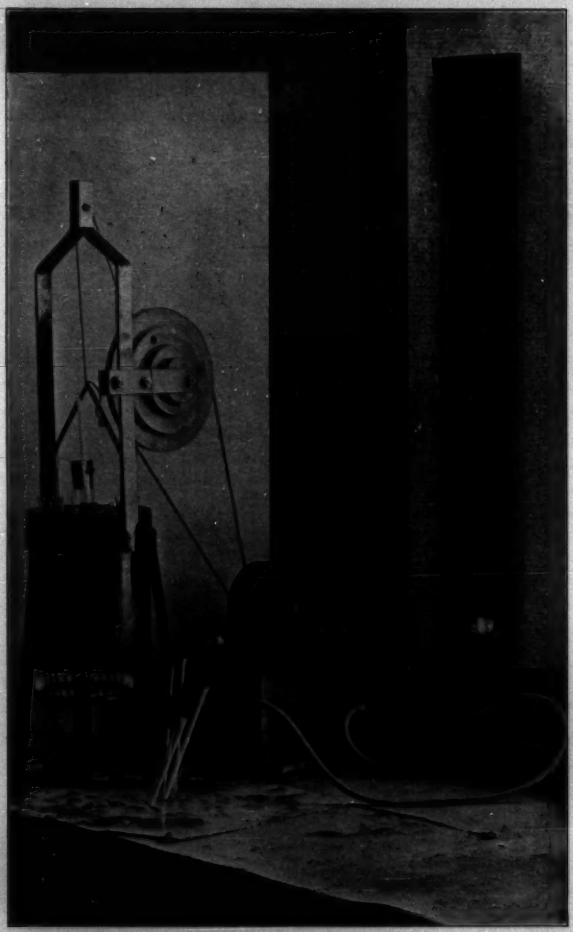

FIG. 2.—Stability tests of nitro-cellulose and nitro-cellulose powders. Explosion-test apparatus.

	Degrees C.
A nitro-cellulose must not explode under	186
" " " powder must not explode under	177
" nitro-glycerin " " " " "	170

Judging from a great number of explosion tests made on nitro-celluloses and on nitro-cellulose powders, it seems that this test is fairly reliable when the explosive is either very good or very bad. Uusually, a good nitro-cellulose will not explode below 186° C., and a good nitro-cellulose powder not below 177° C.; however, there may be variations of + or — 4° from these figures. For example:

Four apparently equally good powders—

	Degrees C.
Nitro-cellulose powder No. 396 exploded at	173
" " " " 797 " "	175
" " " " 799 " "	177
" " " " 800 " "	181

Three other nitro-cellulose powders, showing a very poor stability by all other tests,

	Degrees C.
No. 326 exploded at	161
" 391 " "	168
" 546 F. A. exploded at	170

Variation may be caused by different manipulation of the test, and by the physical condition of the sample. Duplicate samples sometimes vary 3°. On account of the volatility of nitroglycerin, the test is of little value in testing nitroglycerin powders.

The explosion test, therefore, is only a rough guide as to the stability of an explosive, but is of some value when made in conjunction with other tests.

THE THOMAS TEST.

This test* consists in heating the sample in a glass-stoppered tube, in an oil bath, for eight hours daily. A good nitroglycerin powder should stand four days' heating at 94°–96° C. without developing brown fumes (N_2O_4). A good nitro-cellulose and nitro cellulose powder should not show fumes before three days, using a temperature of 99°–101° C.

* *Zeit. Ang. Ch.*, 1898, 1027.

These temperatures are too low to produce a decisive decomposition, which may be observed by the appearance of brown fumes. At 100° C, or below, the decomposition of nitro-cellulose, or nitro-cellulose powder, is often so slow and gradual that it is difficult to say just when brown fumes appear. Captain Aspinwall† cites cases where nitro-cellulose required twenty-one days' heating to show brown fumes and says that the objection to this test is the length of time required to obtain definite results.

THE 135° TEST.

This test, which is also known as "the German test," is made on all nitro-celluloses and powders at this laboratory. It is a combination of several tests used in Germany and Switzerland.

Two and five-tenths grams of the sample to be tested are placed into a strong glass test-tube 320 millimeters long, and 15 millimeters internal and 18 millimeters external diameter; a piece of blue litmus paper is put into the tube about ½ inch above the explosive. The tube (*Fig. 3*, tube shown one-half actual size) is now lightly corked and placed into a bath at 135° C. This bath (*Fig. 3*) is made of heavy sheet-copper and closed at the top, into which are sunk twenty copper tubes closed at the lower end. The bath is about two-thirds full of commercial xylol, having a boiling point of 135° C.; a reflux condenser prevents the volatilization of the xylol. Into the copper tubes, which are surrounded by boiling xylol, are placed the glass tubes containing the explosive to be tested, in duplicate.

Three observations are made: (1) the reddening of the litmus paper; (2) the appearance of brown (N_2O_4) fumes, and (3) the explosion of the sample. The minimum time, as required by government specifications, is as follows:

	Litmus red.	Brown fumes.	Explosion.
Nitro-cellulose	:30	:45	5:00
Nitro-cellulose powder	1:15	2:00	5:00
Nitroglycerin powder	:30	:45	5:00

† *Jour. Soc. Ch. Ind.*, 1902, May 31.

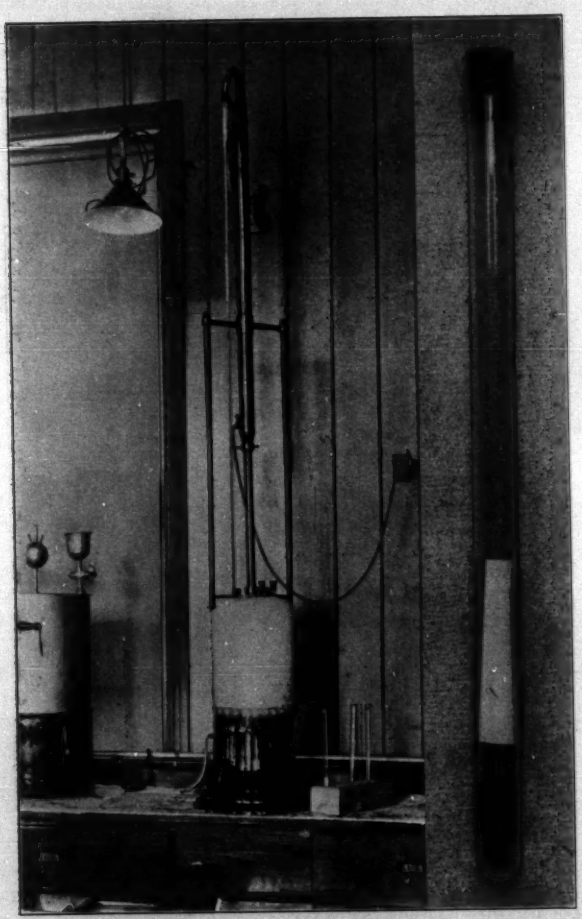

FIG. 3.—Stability tests of nitro-cellulose and nitro-cellulose powders. 135° C. test.

To make the results of this test as valuable as possible all three observations must be carefully studied and compared with those obtained from standard or good products.

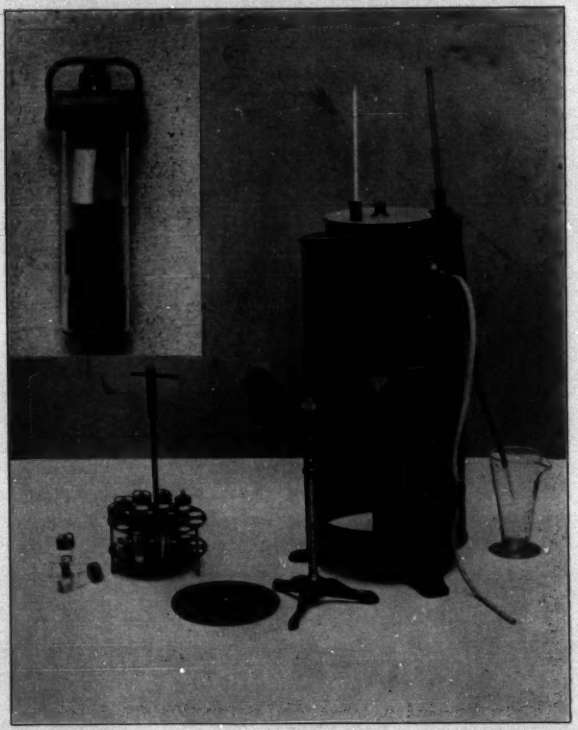

FIG. 4.—Stability tests of nitro-cellulose and nitro-cellulose powders. Vieille's test.

The temperature 135° C. is usually considered too high for stability testing, as it may cause decomposition not always dependent upon the stability of the explosive.

Again, very often it is impossible to say just when the litmus paper is red, and two operators have been known to vary thirty minutes in this observation. The same is true of the "brown fumes" observation, the readings varying from traces to dark fumes. There is never any doubt as to the third observation—the explosion.

Different makes of litmus papers give results for "litmus red" varying considerably. To avoid errors on this account, the litmus papers used by the Ordnance Department are all made, according to specifications, by Eimer & Amend, N. Y., of as nearly uniform quality and sensitiveness as possible.

By keeping all conditions as nearly uniform as possible, and by observing all precautions mentioned, the "135° test" is one of the best of this class.

THE VIEILLE TEST.

Vieille heats the explosive in a closed glass tube until blue litmus paper is turned red. The temperature used is 110° C., which, after having made a great number of experiments, Vieille decided upon as being most suitable for this test. The Vieille test is used by the Ordnance Department on all nitro-celluloses and nitro cellulose powders.

The apparatus used (*Figs. 4* and *5*) consists of a circular double-walled air-bath filled with glycerin between the walls. Near the top and on the outside of the bath there is a gas regulator (*Fig. 5*); its action depends upon the pressure produced by the expansion of the glycerin as it becomes heated and rises in a glass tube in the top of the bath. On the inside of the bath there is a revolving horizontal tray for carrying the bottles which contain the explosive. A port-hole through the walls of the bath, and a reflector for throwing light into the bath, serve for observation of the explosive without opening the top of the bath or taking out the tray. The bottles are 27 by 85 millimeters and are closed air-tight by a metal cover and clamp and a rubber washer. A short thermometer, having a range of 10° (105° to 115° C.) is placed in one of the bottles and the latter closed in the same way as those containing the samples. A second thermometer extends through the cover of the bath into the

interior and serves as a guide to the operator; the temperature which it registers when the bottle-thermometer registers 110° C. is chalked on the bath.

For the test, 10 grams of the sample are taken in normal condition, and in one piece when possible, and placed in a Vieille bottle. A piece of blue litmus paper is inserted half-way between the top of the sample and the cover of the bottle in a scroll or "S" form, so as to allow free access of the fumes to both sides of the paper. The bottle (*Fig. 4,*

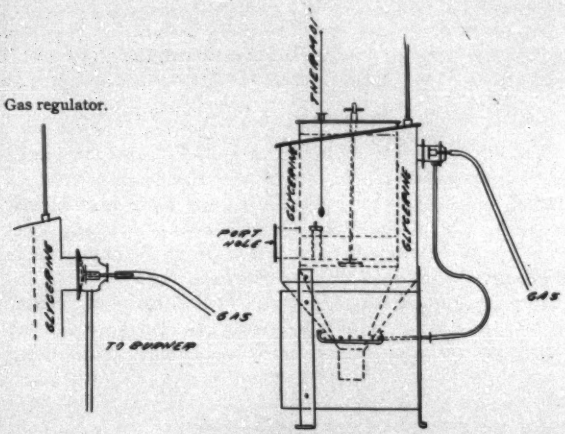

FIG. 5.—Vieille's apparatus.

bottle shown one-half actual size) is then closed and placed in the tray, and the latter put into the bath at 110° C. Triplicates are taken. The bottle is kept in the bath until the paper is thoroughly reddened, the time required is noted, the bottle removed and opened. This operation is repeated daily, using a clean bottle and fresh litmus paper, until the time required to redden the paper in one hour or less. These daily times are added and the total (accumulated time) should not be less than

Thirty hours for large powders,
Twenty hours for small powders,
Ten hours for nitro-cellulose.

Experience at this laboratory proves that this test is not applicable to nitroglycerin powders since they are liable to explode. A temperature of 110° C. is too high to heat confined nitroglycerin powders, since volatilization of nitroglycerin is too great at this temperature.

At first the Vieille test promised good results, but after applying it to nearly 1,000 samples it is found difficult to obtain reliable results. The shortcomings of the test are:

(1) In common with all other heat tests when blue litmus is used, it shows only acid products of decomposition.

(2) It is practically impossible to get all the Vieille bottles equally tightly closed. Experiment has shown that pressure is an important factor in the decomposition of nitro-cellulose products; the greater the pressure the less the stability time.

(3) The personal equation of the observer in reading the reddening of the litmus paper.

(4) Varying results are obtained unless the litmus papers be uniform.*

To show how (2) and (3) may affect the test, the following example is given. Powder used, No. 374; three bottles, prepared as nearly alike as possible; readings taken by operator who usually makes this test:

	1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	Total.
1	5.15	3.20	3.00	2.40	2.05	1.35	17.55
2	5.15	4.00	3.00	2.10	1.10	1.30	17.05
3	5.15	3.20	3.00	2.40	3.00	2.20	19.35

THE WILL TEST.

Of the tests so far described, some show only the beginning of decomposition, while others show the beginning and

* The litmus papers used at this laboratory are the same as described under the "135° C. Test."

roughly also the progress of decomposition. None can properly be called a quantitative test.

No better reasons for the need of an entirely new test, and one that is quantitative, could be given than those of Professor Will in his report of December, 1900, in "Mittheilungen a. d. Centralstelle f. Wissenschaft. Untersuchungen," Neu Babelsberg, near Berlin (abstract in *Journ. Soc. Ch. Ind.*, June 30, 1900). He enumerates the deficiencies of the tests now in general use, and our own experiences, as mentioned under the above-described tests, fully agree with what Professor Will says.

Will's test consists in decomposing nitro-cellulose at 135° C. in a stream of carbon dioxide, reducing and absorbing all products of decomposition so as to leave only nitrogen gas, which is measured at regular intervals in a burette, and the rate of evolution of nitrogen is taken as an index of the decomposition. The use of such a high temperature as 135° C. necessitated an investigation to determine whether a definite relation exists between different temperatures and rates of decomposition; *i. e.*, whether the stability or decomposition of a nitro-cellulose varies regularly with the temperature. It could be safely assumed that the stability of a nitro-cellulose decreases and decomposition increases as the temperature to which it is subjected increases. Will's exhaustive experiments prove that such parallelism exists. Vieille's experiments, cited by Captain Aspinwall (*Journ. Soc. Ch. Ind.*, May 31, 1902), show that a distinct relation exists between time and temperature to which a nitro-cellulose, or powder, may be exposed before breaking down.

Will's apparatus is shown and described in his second report, January, 1902. It consists of (1) a Kipp generator for making carbon dioxide; (2) decomposition tube, for heating and decomposing the sample; (3) reduction tube, for reducing nitrogenous products of decomposition to nitrogen; this tube contains spirals of copper-wire gauze; (4) gas burette, for collecting and measuring the nitrogen; (5) metal shield for protecting operator in case of explosions. After placing the sample in (2), the whole apparatus is connected air-tight, and a slow stream of carbon dioxide is

passed through until all air is driven out. By means of an oil-bath the tube containing the sample is heated to and kept at 135° C.; a slow, uniform current of carbon dioxide carries the products of decomposition into the reduction tube, and from there into the burette, which is filled with a strong solution of sodium hydrate; the volume of the nitrogen gas is read every fifteen minutes.

A nitro-cellulose, which by this test gives equal quantities of nitrogen in equal intervals of time, Will considers as being stable, or in "the limit state" of purification.

Considering the main principle of this test, and in theory, it should give better results than those obtainable by any other test so far described. Will's test was thoroughly tried by Mr. C. P. Beistle, of this laboratory, no expense nor time being spared in setting up the rather elaborate apparatus required and in conducting the test. A number of tests were made, but the results obtained were unsatisfactory and the test was discontinued. Briefly, the following reasons are given as the cause of unsatisfactory results:

(1) The temperature of 135° C. is too high for stability-testing purposes.

(2) The decomposition is measured only by the nitrogen evolved.

(3) From Professor Will's experiments and diagrams it is not at all clear where to draw the line (except very roughly and in a most general way) between a stable and an unstable product.

(4) The statement is made that for a certain nitro-cellulose, heated for thirty hours and losing one-fourth its original nitrogen, the evolution of nitrogen in equal intervals of time was identical; while in another place it is stated that 10 grams of nitro-cellulose gave 4 times the quantity of nitrogen that were given off by 2·5 grams. It is not easy to understand how it is possible, even in a perfect product, to get equal quantities of nitrogen in equal intervals of time, since the amount of unchanged material is constantly decreasing. The two statements therefore seem contradictory.

(5) It is practically impossible to get a carbon dioxide which is free from air; and as it is exceedingly difficult to

pass the carbon dioxide through the apparatus at a uniform rate, the air-content of the gas gives rise to serious errors. Further, if the carbon dioxide is conducted too fast it cannot be sufficiently heated in the pre-heating coil before it comes in contact with the sample, and may not be completely absorbed by the soda solution. If the current be too slow, the gases of decomposition are not carried away fast enough, and this may affect the course of the decomposition.

(6) If the reduction tube and copper spirals are not heated sufficiently high, or the current of carbon dioxide passed too fast, some of the products of decomposition may escape reduction and will not be absorbed by the soda solution.

(7) Quite unstable products are liable to explode, which might cause considerable annoyance, both to the operator and the apparatus.

From what has been said about these methods of testing, it is obvious that the stability of an explosive cannot be determined from any one method alone. At this laboratory, the Abel or potassium-iodide starch test, the explosion test, the 135° C. test and the Vieille test are made on all nitro-celluloses and nitro-cellulose powders. A careful application of these four tests will detect an unstable product.

CHEMICAL LABORATORY, FRANKFORD ARSENAL.
PHILADELPHIA, January 2, 1903.

CEMENT FOR MARBLE.

The *Bandische Landes Zeitung* says that an excellent cement for broken marble consists of 4 parts of gypsum and 1 part of finely powdered gum arabic. Mix intimately, then with a cold solution of borax make into a mortar-like mass. Smear on each face of the parts to be joined, and fasten the bits of marble together. In the course of a few days the cement becomes very hard and holds very tightly. To get the best results the object mended with the cement should be left absolutely quiet for several days, not touching or moving it. In mending colored marbles the cement may be given the hue of the marble by adding the color to the borax solution.

CHEMICAL SECTION.

Stated Meeting, held Thursday, January 23, 1902.

Modern Methods of Rock and Mineral Analysis.

By Dr. W. F. Hillebrand,
U. S. Geological Survey, Washington, D. C.

(*Concluded from p. 126.*)

This ready oxidizability of titanium offers an easy means of separating zirconium from it quantitatively. It is only necessary after peroxidizing in not too strong sulphuric solution to add a soluble orthophosphate, whereby zirconium is quantitatively precipitated at once, if even only a few milligrams are present, more slowly if in smaller quantity.

This method, which seems to be good, doubtless admits of a separation of large amounts of zirconium from titanium; though if it were easy to obtain and always have on hand a strong and pure hydrogen peroxide it might be very advantageously employed alone without a phosphate, both as oxidizer for titanium and precipitant for zirconium in the state of superoxide, as first employed by G. H. Bailey. Either, however, necessitates resolution and reprecipitation, the final absence of the titanium peroxide coloration being a sure sign of complete removal of that element. Prior to the publication of Bailey's work there was no means of separating with any certainty the zirconium in rocks, hence the frequent failure to recognize it as a rock constituent.

Another method, similar in principle to the old titanium method, has been applied by Baskerville to separation of both titanium and zirconium from aluminum and iron, and with very considerable success. It consists in boiling, for only a few minutes, the chloride instead of sulphate solution, previously nearly neutralized with ammonia, in presence of sulphur dioxide. While it promises well, its general applicability has not yet been tested, but it is certainly vastly preferable to its prototype.

Directly connected with the presence of titanium in rocks, clays and many ores is a modern modification in the volumetric method of total iron estimation. Reduction by nascent hydrogen prior to titration involves an error when titanium is present, by its partial reduction to a lower oxide, hence the necessity for a method of reduction which should eliminate this error. It was found in the substitution of hydrogen sulphide for hydrogen, followed by boiling out the excess of reducing agent and cooling in a carbon-dioxide atmosphere. This elegant method, too little employed as yet, affords irreproachable results, and it is not even necessary to remove by filtration the sulphur which separates as a result of oxidation of the hydrogen sulphide, unless metallic sulphides are mingled with it, for on pure sulphur in the cold permanganate is without action.

Since vanadium is, like titanium, an extremely common constituent of nearly all rocks, and hence of soils and clays, and if present is one of the components of the familiar mixture we are still discussing, its influence on the estimation of total iron must be considered in all very refined work. This, of course, can only be done when the percentage of vanadium is known, in which case it is only necessary to allow for its oxidation from V_2O_4 to V_2O_5 (after reduction by hydrogen sulphide, but not by hydrogen) in order to obtain the correction for total iron.

Since vanadium occurs in soils and rocks apparently in the trivalent state, replacing aluminum or ferric iron in certain silicates, it must necessarily be allowed for in determining the ferrous iron that may exist in a rock or mineral. Here, of course, it consumes twice as much oxygen in being converted to V_2O_5 as was the case in estimating total iron, where it had only to be oxidized from V_2O_4 to V_2O_5. This correction is readily applicable by either of the two methods in vogue for determining ferrous iron, provided there are absolutely no traces of sulphides present.

With regard to the old Mitscherlich method for determining ferrous iron, by heating in a sealed tube with sulphuric acid, it has been shown that unless the tube is filled with carbon dioxide gas passing in a current up to the very

instant of sealing the tube, instead of by the very unreliable one of introducing sodium carbonate crystals or solution, the results will inevitably be low, for only in the former way can complete exclusion of air and consequent success be secured.

I said just now that only in absence of sulphides could the proper correction for V_2O_3, if present, be applied when using the Mitscherlich or sealed-tube method, and this for the same reason that makes the presence of these sulphides fatal to the ferrous-iron estimation itself. It was only when the almost never-failing presence of sulphides in all sorts of rocks became impressed upon me, by persistent testing for sulphur in them, that their influence in explaining certain marked discrepancies between results by the Mitscherlich and the hydrofluoric-acid methods of ferrous-iron estimation became apparent. It would perhaps not then have impressed itself but for the rediscovery by Stokes of the powerful reducing action of metallic sulphides on ferric salts, first announced by L. L. de Koninck. This action fully suffices to account for the excess of ferrous oxide (running all the way from nothing up to 2 or more per cent.) by the Mitscherlich method as against that by hydrofluoric acid, an excess which I recognized fifteen years ago, but had hitherto been unable to account for. Thus we are enabled to see that all, or nearly all, the early analyses of rocks, in so far as they contained sulphides, or carbonaceous matter, are affected by an indeterminable error. And since to the petrographer the exact determination of the two oxides of iron in a rock is of great importance for the calculation of the mineral constituents, it is clear that not much can be done with most of the analyses made before the introduction of the Cooke or hydrofluoric method about 1867. Fortunately, at the temperature of boiling water, the action on ferric salts of the relatively small amounts of pyrite found in rocks is insufficient to produce a serious error in the ferrous-oxide determination. Nevertheless, since other sulphides, which are readily soluble in hydrofluoric and sulphuric acids, as pyrrhotite, frequently do occur, it is manifest that an error is introduced of another kind which it is

next to impossible to allow for with any degree of certainty. Hence, although we have seen our way to overcome certain difficulties in its determination, we are still in want of a method which shall at all times give the true value for ferrous oxide, and consequently for ferric oxide, for an error in one is accompanied by its twin of opposite sign in the other.

Chromium, which may likewise form a part of our mixture, is readily determinable, and with great exactness, by a recent colorimetric method when it occurs in small amount, as is always the case in rocks and iron ores. This method consists in obtaining the chromium as chromate in alkaline solution of known volume and comparing its color with that of a standard monochromate solution. For large amounts I know of no special improvements in the older methods, but may say that the separation from alumina by hydrogen dioxide, announced a few years ago, is, like so many similar methods, not reliable.

I shall say little with regard to phosphorus, except that the causes for many discordant statements have been shown to lie in the varying composition of the ammonio-magnesian precipitate. Unless this is caused to form under certain conditions not always attainable, it will not on ignition have the normal pyrophosphate composition. Therefore, if the precipitate is at all large it is recommended by Gooch and Austin to decant, to redissolve the precipitate in as little hydrochloric acid as possible, to reprecipitate by dilute ammonia without further addition of magnesia mixture, and to wash finally with weakly ammoniacal water. Excess of ammonia, of ammonium salts and of precipitant are all objectionable. By decantation, without washing, enough of the precipitant is supposed to be retained to render further addition needless.

Rare earths may at times help to compose our now familiar mixture, but in such small traces as a rule, and so seldom looked for, that I will not take up your time by further allusion to them, except to say that as a group they can be separated and recognized without excessive trouble even when present in but a fraction of a milligram. The

ways of separating the members of this group are mostly based on long-known reactions, of which perhaps only one comparatively recent application in either qualitative or quantitative analysis deserves a word of comment. This depends on the insolubility of the fluorides of all the rare earth metals, without exception, in weak hydrofluoric acid. By the aid of it we are enabled to separate the entire group from all elements whose fluorides are soluble, provided there are no combinations present which will furnish insoluble double fluorides. Hereby, the analysis of such minerals as tantalite, columbite and samarskite is materially simplified and the detection of zirconium in presence of the earths is rendered easy. Moreover, the insolubility of its fluoride is a characteristic of uranium in the tetravalent state, but not in the hexavalent, so that we are hereby furnished with a means not only of separating these two uranium kations from one another, but also of ascertaining with ease the condition of uranium in a mineral by its appearance in the filtrate in one case or precipitate in the other when a mineral containing it is decomposed by hydrofluoric acid.

Now, as to that component, finally, of our mixture which, as I have already intimated, is so difficult of direct estimation when mingled with numerous other bodies, especially if phosphorus is one of these. To take up the reasons for this difficulty in detail would lead too far. Suffice it to point out wherein we have improved or learned to reject older methods of separation, then to mention one or two newer ones.

Of the two old standby methods for separating aluminum from iron, by a fixed caustic alkali and by ammonium sulphide in tartrate solution, the former has been improved by fusing the solid mixture in a silver crucible instead of boiling its solution with the alkali. Hereby the separation is said to be rendered perfect, but both modifications labor under the disadvantage that if titanium is present—and in a rock analysis it always is—this goes to a small extent into solution with the aluminum, unless iron is simultaneously present in large excess. Many old analyses are therefore

affected by a slight error on this account, and even some foreign ones of to-day, for the method is still more or less in vogue abroad.

Of late years the search for organic precipitants of certain metals has been rather active, especially for those metals for whose separation good inorganic reagents are lacking. A number of such have been proposed, and among them phenylhydrazine as a precipitant for aluminum in presence of iron after reduction of the latter by a sulphite. Hess and Campbell, the discoverers, claim complete insolubility of the aluminum hydroxide in this reagent. Experiments made by Dr. E. T. Allen in our laboratory as to the availability of this method in presence of the usual rock constituents indicate that it is not available in presence of titanium and zirconium, for the reason that they are also thrown down. Since aluminum phosphate is likewise precipitated by phenylhydrazine, this reagent for ordinary rock analysis probably offers no anvantages over those commonly used. Moreover, it oxidizes rapidly, forming a brown scum, which is strongly adherent to the vessel and resembles ferric hydroxide so much as to greatly confuse the operator. Still, since the colorimetric as well as the gravimetric method for estimating titanium requires preliminary removal of iron when this is present in large quantity, the phenylhydrazine method may prove to be advantageous, since by it the aluminum, titanium and zirconium are obtained at once as a precipitate, and do not have to be recovered by a somewhat tedious operation from the tartrate filtrate from the iron sulphide.

With reference to manganese, the reasons why the results of precipitation as ammonio-manganous phosphate have not always been satisfactory have been worked out by Gooch and Austin. They have shown the cause to lie in the incomplete conversion of the first precipitated tri-manganous phosphate to the double salt, and claimed that to the attainment of satisfactory results the solution should contain not less than 10 per cent. of ammonium chloride. Very soon after this Dakin published a paper in which he showed that by precipitating with diammonium hydrogen

phosphate under very easily regulated conditions and in absence of any unusual amount of ammonium chloride a salt of normal condition was obtained, and that the final results were equally good, whether this was weighed as an ammonium salt by drying at 100°–105°, or as pyrophosphate.

He had already employed the same process with zinc, and extended it also to cobalt, with most excellent results in both cases.*

Because of the inconstancy in composition of manganomanganic oxide, obtained by ignition of precipitated carbonate or peroxide, that mode of determining manganese has fallen somewhat into disfavor, and as a substitute the old method of converting to sulphate has again been brought into favor by Gooch and Austin, who show that it is expeditious and accurate when properly performed. In general it may be said that the principle of weighing as sulphate with accuracy has been extended to other metals with success as zinc, nickel, cobalt.

A further and convenient method for bringing magnesium, zinc, cadmium, manganese and nickel into the convenient forms of oxides is that first employed by Berzelius and extended by Volhard, Zimmermann, and Smith and Heyl. It consists in the evaporation and ignition of the chloride with an emulsion of pure mercuric oxide in excess. This principle is also sometimes applied to the removal of small amounts of magnesium in alkali determinations.

As with manganese the conditions favoring the precipitation of ammonio-magnesian phosphate of normal composition have been studied by Neubauer and also by Gooch and Austin, with the result that we now know that excess of precipitant, of ammonium salts, and of ammonia are all prejudicial to the formation of a precipitate which on ignition shall give only pyrophosphate. Usually the precipitate contains an admixture of a more highly ammoniacal phos-

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*Austin (*Am. Jour. Sci.*, August, 1902), has since taken exception to the conclusions of Dakin, and shown the probable existence of errors in the methods of analysis on which those conclusions were based.—W. F. H.

phate giving metaphosphate on ignition. Gooch, in particular, has tried to secure conditions of precipitation leading to the formation of normal ammonio-magnesian phosphate, while Neubauer seeks to obtain the pyrophosphate rather by long and strong blasting of the precipitate, whereby the excess of P_2O_5 is volatilized.

No one in careful work nowadays contents himself with a single precipitation of calcium as oxalate in presence of magnesium and alkalies, because of the well-understood contamination by these others. Only recently has T. W. Richards, in conjunction with some of his students, studied fully the subject of occlusion of magnesium oxalate by calcium oxalate and shown how by the observation of certain conditions results which are satisfactory by a compensation of slight errors are attainable by a single precipitation. Because of the lengthy personal attention of the operator it is possible that this simplification will not commend itself to general use, especially where much work is going on. Richards has also confirmed the determination of others regarding the solubility of calcium oxalate in water and found that 1 liter of boiling water dissolves over 1 centigram of oxalate. Hereby is shown the necessity for abandoning the practice followed by some chemists of long washing of the oxalate with excessive quantities of boiling water, though, of course, the rapid passing of wash-water through the filter would not extract the maxium amount of oxalate.

The old practice of determining water in rocks and many minerals by loss on ignition is now relegated to the garret for antiquated methods by all who can make any pretensions to careful work. As there is no rule without its exception, so here there are cases in which water can be estimated by loss on ignition with even greater certainty than by any direct method, but no such result can be accepted as above suspicion unless the composition of the body is otherwise known in great detail. The "loss" is often, especially in rock-work, the algebraic sum of several factors, some of which may have positive, others negative signs. Thus it quite often happens that, besides water, the loss is com-

pounded of one or more of the following factors: Carbon dioxide, sulphur or sulphur trioxide or both, hydrofluoric acid, silicon tetrafluoride, organic matter, nitrogen, helium, ammonia or ammoniacal salts, and even oxygen resulting from manganese dioxide, for instance. These losses may be offset by a gain of oxygen if fixed oxidizable substances are present, such as sulphides, and ferrous or manganous compounds, especially the carbonates. Of the above, the SiF_4 and the HFl result doubtless from chemical reaction at high temperatures in fluosilicates and hydrous fluorides respectively, the latter reaction being similar to that by which hydrochloric acid is given off on evaporating to dryness solutions of magnesium or aluminum chloride.

Again, it is now known that hydroxyl radicals cannot always be broken up in minerals with expulsion of water by the application of heat, even that of the blast-lamp, but that complete destruction of the molecule is essential. To the application of this discovery we owe our present knowledge of the composition of topaz and some other minerals, which contain not only fluorine but hydroxyl as well, undoubtedly, in isomorphous replacement of each other.

Therefore, in order to avoid errors in determining water, it is now customary to fuse the mineral in a suitable apparatus with a flux—either sodium carbonate, lead or bismuth oxide, or borax, in order to prevent the loss of other constituents.

[At this point Gooch's tubulated crucible was exhibited and described.]

I spoke a moment ago of the replacement of fluorine by hydroxyl in some minerals. This was first perceived and pointed out by Penfield, who has done so much to clear away the mists surrounding the composition of many minerals. And it is by the recognition of this isomorphism of fluorine and hydroxyl, particularly, that hitherto inexplicable formulas have been made plain, and suspected but ill-understood relations have received rational explanation.

Many zeolites have long been known to give off a good deal of water below the boiling-point. This has ordinarily been held to be of a hygroscopic nature, despite the fact that

the curve showing the rate of loss suffered no abrupt change of direction at 100°, but continued to rise with increasing temperature. This made it extremely difficult to arive at any conclusions as to the number of molecules of water of crystallization that should be assigned to these minerals, no two analysts coming to quite the same conclusions, and the results representing often quite improbable fractions of molecules. The lately deceased Charles Friedel succeeded in explaining this peculiar behavior very satisfactorily by showing that this "zeolitic" water was not held as water of crystallization is supposed to be held, but more like that absorbed by a sponge; that some was still retained up to the temperature which disrupted the molecular net, and, that when cooled down again short of the attainment of this limit, the whole of the expelled water could be regained. Not only this, but that after expulsion of the water its place could be supplied by air, or ammonia gas, or carbon disulphide vapor, or alcohol vapor, etc., if the mineral were cooled down in the proper atmosphere, and that the amount absorbable is within certain limits a function of the vapor pressure. Thus we see that the water of some zeolites, at least that expelled at temperatures short of rupture of the molecular structure (often 10 to 18 per cent.), is no longer to be counted in the formula as water of crystallization.

In respect to the alkalies no marked changes in methods have been introduced beyond the convenient Gooch method for separating lithium from potassium and sodium in place of the old and unsatisfactory phosphate method. Gooch's method depends on the solubility in absolute amyl alcohol of lithium chloride and the insolubility of the other chlorides.

The most interesting novelty with reference to the determination of the SO_4 ion has connection with its precipitation as barium sulphate in presence of a ferric salt. This last, as you all know, is carried down with the barium apparently in the form of an insoluble complex sulphate, from which very serious errors result, which are greater in hot than in cold solutions. By operating in the cold, the formation of the ferric-sulphate ion-complex is so repressed

that fairly satisfactory results may be secured, but the best way is to avoid the possibility of their formation at all by removing its ferric ions from the solution before adding the barium chloride. This has long been done by the inconvenient method of fusing with an alkali carbonate and leaching with water. Far simpler is the procedure of Lunge, as modified by Küster and Thiel, whereby the iron is first precipitated by ammonia, then the SO_4 by barium chloride without first filtering, after which the iron is redissolved by hydrochloric acid and the barium sulphate left in pure condition.

For boron, we owe to Gooch and Rosenbladt independently a method which affords excellent results in the case of simple borates soluble in acids, but for some unexplained reason not always if they have first to be decomposed by fusion with an alkali. The method depends on expelling the boron as methyl borate by distilling with repeated portions of methyl alcohol the solution made slightly acid by nitric or acetic acid. The distillate is caught in a receiver containing slaked lime or ammonia. If the latter, this is later poured upon a known weight of slaked lime and the mixture is evaporated carefully and ignited over the blast. The increase gives the boric oxide.

For very small amounts of boron, however, the method is not available, and we unfortunately lack a method for its estimation in such cases.

The same may be said of glucinum, which is so little characterized by distinctive reactions capable of being made the basis for quantitative separations that we are as yet unable to detect this element in rocks with certainty. At least its detection is hampered by so many difficulties and uncertainties that the search for it is rarely undertaken. It and boron are certainly frequent constituents of some rocks, and convenient methods for their detection and isolation are much desired.

In a less degree this is true for fluorine, for whose separation we must still usually resort to the Berzelian method. When in quantity and not accompanied by phosphorus this old standby can afford fairly satisfactory results, but if the

amounts are small the difficulty of removing all traces of silica, etc., makes the results more or less approximate.

In the foregoing I have purposely confined myself largely to consideration of those processes of separation and determination which are of everyday or at least frequent occurrence in the work of the mineral chemist, and even of the technical chemist who works on inorganic lines—methods with which, in principle at least, many of you may be supposed to be well acquainted. To have touched even lightly upon special cases, as the assay of uranium and vanadium ores, the analysis of complex sulphides or unusual minerals of any sort, was quite out of the question. Even in what has been said, the subject has in no case been exhausted, nor have I been able to bring up all, even of the most important points that might have been touched upon. Enough has been said, I think, to show the general trend in analytical work toward the perfection and better understanding of old processes quite as much as the invention of new ones, and it is along this line that some of the best work has been done. As a further instance, I may mention the action of caustic alkalies on silica. It was long almost a principle of faith among mineral chemists that quartz was unaffected by solutions of the alkalies. How little foundation this belief had, the work of Lunge and Millberg has conclusively shown. From it, it appears that (given a sufficient degree of fineness) quartz powder is readily soluble, and that the solubility of silica in its different forms is but a function of its physical condition. Hence, methods for the determination of opaline silica in presence of quartz based on the solubility of the former in caustic-alkali solution can give at the best only approximate results, and these may be often totally wrong.

Enough has been said to show how far from being an exact art rock analysis is. It will, moreover, doubtless become more and more intricate as means are devised for detecting and estimating constituents which we now ignore or only suspect to exist in our material. But with these methods will come knowledge of the distribution of those elements such as has been already acquired with regard to

vanadium in rocks and to a less degree molybdenum. Thus, we know that with very siliceous igneous rocks it is usually unnecessary to look for vanadium, and in very basic ones for molybdenum. The same will be true in time for other elements, and our work will be lightened in degree as knowledge is gained of their relative abundance and distribution.

One of the most interesting problems confronting the mineralogist is that relating to the condition of nitrogen and helium in certain minerals, mostly those containing thorium and uranium—the two elements of highest atomic weight. It is because of the very high atomic weight of most of the metals in heliferous minerals that the relatively very small percentages of the light helium and nitrogen become of moment in the establishment of proper formulas for them. It seems very probable that these gases are not occluded, in the ordinary sense, but are in chemical combination, and if so, even two or three-tenths of one per cent. of helium must require for any sort of combination so large a weight of metal as to render vain any calculations from which it is omitted.

The search for and separation of small amounts and even traces of rock constituents is the most delicate part of rock analysis, and one which is calculated to tax to the utmost the ingenuity and patience of the conscientious worker. It is, I think, a feature of analytical work which might be cultivated with great profit in our educational laboratories. Oftentimes the methods applicable to the separation of very measurable amounts of various bodies refuse service or must be applied with special precautions when but traces of them are at hand, and this important knowledge the student seldom acquires as part of his regular instruction. I can conceive of no more valuable experience to an advanced student than a thorough initiation into the mysteries of a complex-rock analysis wherein not only the main components but all the lesser ones are carefully sought for and identified. This often involves considerable qualitative work of much value. There is, too, a satisfaction to be derived from the successful separation and identification of traces in a

complex mixture not inferior to that afforded by a clean separation of those same bodies in large amounts. By carefully carrying out such an analysis under competent guidance the student will acquire a fund of information that will broaden his ideas of chemical combinations and analytical research and be of more value to him than any one or several analytical investigations that I can think of. But the instruction should be thorough and should go into all the details of looking for traces and obtaining the proper corrections for any impurities that the weighed precipitates may ordinarly be expected to contain. Most instructors, it may be objected, do not have the time to acquire themselves the knowledge of detail needed for this work. But against this it may be said that every large educational institution can well enough afford an instructor who among his other specialties is versed in the intricacies of such work.

That knowledge of this kind is abundantly needed in many lines of work events have too often shown. He will be of greatest value in technical work who possesses knowledge beyond that of the immediate needs of oftentimes approximate commercial demands; for he, far better than the rule-of-thumb worker, will be able to recognize when his work goes wrong, which is often a far more difficult matter than to know when it is right.

SOLDERING WITH NASCENT BORAX.

In hard soldering with borax, direct, there are several little difficulties encountered that make the process somewhat difficult. In the first place the salt forms great bubbles in contact with the soldering-iron, and easily scales away from the surface of the parts to be soldered. Besides this, the parts must be carefully cleaned each time prior to applying the salt. All these difficulties vanish if instead of borax we use its component parts, boric acid and sodium carbonate. The heat of the soldering-iron acting on these causes them to combine in such a way as to produce an excellent flux, free from the difficulties mentioned.—*Drug. Circ. and Chem. Gaz.*

PHYSICAL SECTION.

Stated Meeting, held February 27, 1901.

On the Mathematical Theory of the Geometric Chuck.

By E. A. Partridge, Ph.D.

(*Concluded from p. 146.*)

Calling the instant at which p_1 and p_2 are simultaneously equal to zero, the zero point of time, we have the following expression for the rectangular co-ordinates of the point E at any time t.

$x = e_1 \cos a_1 wt + e_2 \cos a_2 wt + e_3 \cos (p_3 + a_3 wt) + e_4 \cos (p_4 + a_4 wt) + e_5 \cos (p_5 + a_5 wt)$.

$y = e_1 \sin a_1 wt + e_2 \sin a_2 wt + e_3 \sin (p_3 + a_3 wt) + e_4 \sin (p_4 + a_4 wt) + e_5 \sin (p_5 + a_5 wt)$.

The curves traced by the geometric chuck are all algebraic.

The *v's* are all integers or rational fractions; in the latter case the value of a_1 is necessarily chosen so as to make all the *a's* integers. Hence, we have the co-ordinates x and y expressed as the sum of sines and cosines of multiples of wt. The sines and cosines of multiple angles can be expressed as the sum of powers of the sine of the the simple angle affected with numerical coefficients. If the multiple is an even multiple of the simple angle, its sine can be expressed in powers of the sines with the factor $\cos wt$. If the multiple be odd, it can be expressed in powers of the sine without the cosine factor.

The cosine of an even multiple angle can be expressed as a sine of powers of sines simply affected by numerical coefficients, but if the multiple be odd in addition to numerical coefficients, we have the factor $\cos wt$. Then, in any case, by transposing all the terms affected by the factor $\cos wt$ to one side and squaring we can express x^2 and y^2 in terms of powers of $\sin wt$ and numerical coefficients.

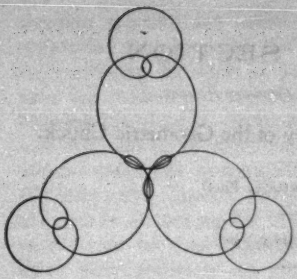

FIG. 19.

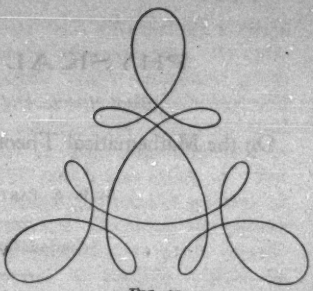

FIG. 20.

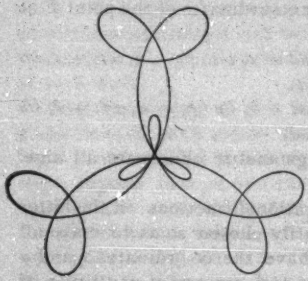

FIG. 21.

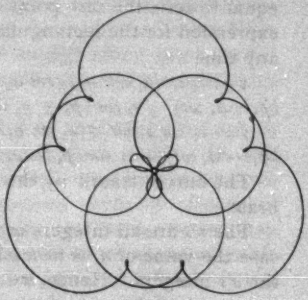

FIG. 22.

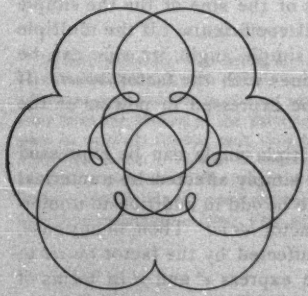

FIG. 23.

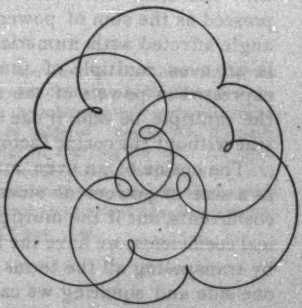

FIG. 24.

Then eliminating *sin wt* by the dialytic method we have an equation between x and y. Hence, the curves are all algebraic.

The curves traced by the geometric chuck are all of even order.

This follows from the fact that from the method of their generation they are all closed curves.

The deficiency of the geometric chuck curves is always zero.

It will, of course, be inferred, from the mode of generation, that the curves are unicursal, but the analytical demonstration is very simple. Having developed the parametric expressions for x and y in powers of *sin wt* with the factor *cos wt* make the following substitutions:

Let $wt = 2\delta$ and $\tan \delta = d$

then $$\cos wt = \cos 2\delta = \frac{1 - \tan^2\delta}{1 + \tan^2\delta} = \frac{1 - d^2}{1 + d^2}$$

$$\sin wt = \sin 2\delta = \frac{2 \tan \delta}{1 + \tan_2\delta} = \frac{2d}{1 + d^2}$$

Since we have developed x and y in powers of *sin wt* and the factor *cos wt*, by substituting the above values for *sin wt* and *cos wt*, we have expressed x and y rationally in terms of a single parameter. Hence, the curves are unicursal. (Jordan: "Cours d'Analyse," Vol. I, §598, 599.)

The degree of the curves is $2n$ where n equals the greatest of the a's.

In the resultant of two equations the coefficients of each equation enter in the degree of the variable in the other. Hence, that which determines the degree of the resultant in x and y is the degree of the highest power of *sin wt* or the degree of the highest power of "d" after having made the substitution considered in the last paragraph. Now, the highest power of *sin wt* results from the highest multiple of *wt*; that is, the largest "a."

Suppose this largest $a = n$. If n is even, then the highest power of *sin wt* resulting from *sin nwt* will be the $(n - 1)$

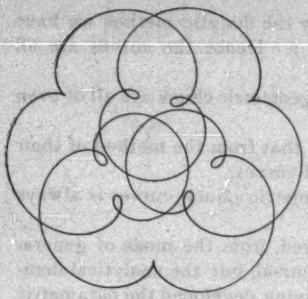

FIG. 25.

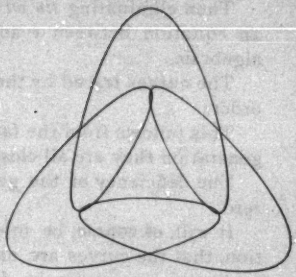

FIG. 26.

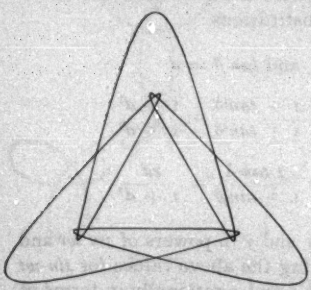

FIG. 27.

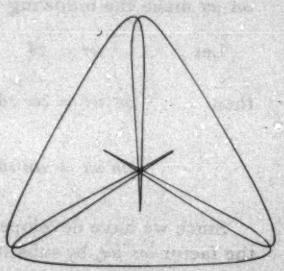

FIG. 28.

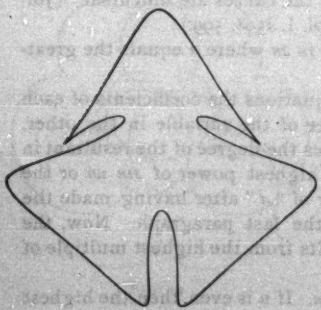

FIG. 29.

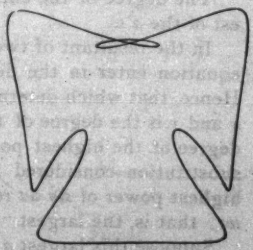

FIG. 30.

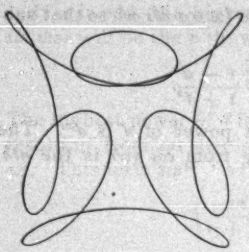

FIG. 31.

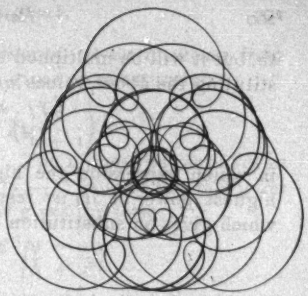

FIG. 32.

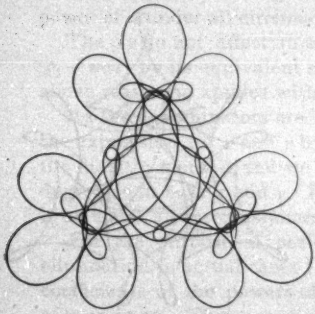

FIG. 33.

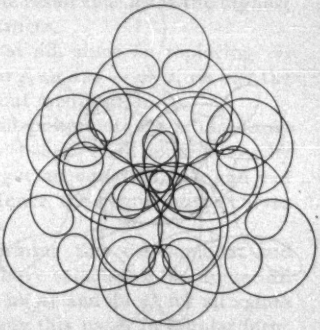

FIG. 34.

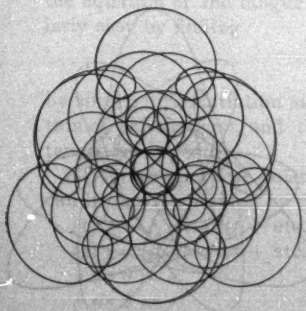

FIG. 35.

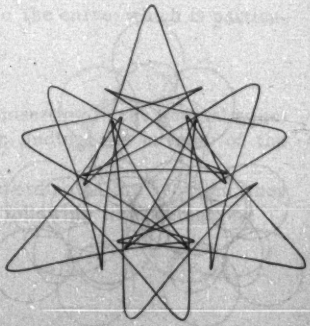

FIG. 36.

th, but it will be multiplied by the factor *cos wt*, so that substituting the above values we get

$$\left(\frac{2d}{1+d^2}\right)^{n-1} \times \frac{1-d^2}{1+d^2},$$

in which expression the highest power of d is d^{2n}. The highest power of *sin wt* resulting from *cos nwt* is the *nth*, which gives on substitution

$$\left(\frac{2d}{1+d^2}\right)^{n},$$

in which d^{2n} is the highest power of d.

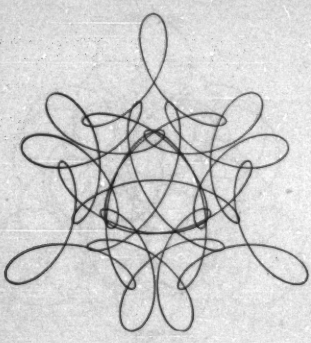

FIG. 37.

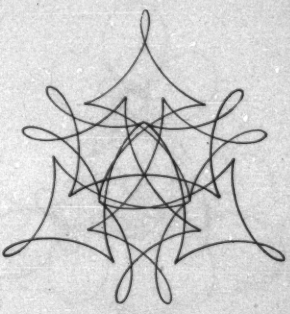

FIG. 38.

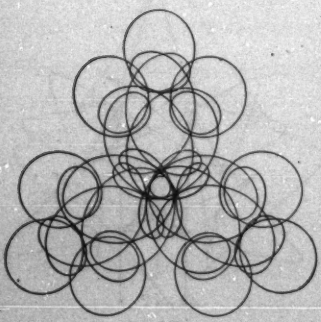

FIG. 39.

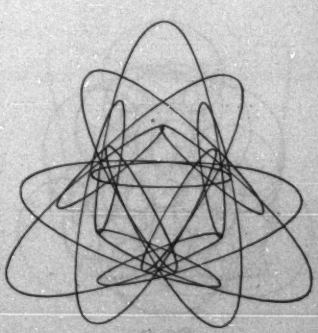

FIG. 40.

If n is odd, the highest power of $\sin wt$ resulting from $\sin nwt$ will be the n th, which gives on substitution

$$\left(\frac{2d}{1+d^2}\right)^n.$$

The highest power of d is d^{2n}. The highest power of $\sin wt$ resulting from $\cos nwt$ is the $(n-1)$ th with the factor $\cos wt$. This term $\sin^{n-1} wt \cos wt$ gives the term

$$\left(\frac{2d}{1+d^2}\right)^{n-1}\left(\frac{1-d^2}{1+d^2}\right)$$

in which the highest power of d is d^{2n}.

From the analysis we get the result that d^{2n} is the highest power of d under all circumstances.

The p's do not affect this at all, since on replacing $\cos(p_3 + nwt)$ by its equivalent $\cos p_3 \cos nwt - \sin p_3 \sin nwt$, the above reasoning applies without modification.

As the denominators are all powers of $(1+d^2)$ multiply the expression for x and y by $(1+d^2)^{2n}$ and eliminate d by the dialytic method, and we get an equation in x and y of degree $2n$ in both x and y. Hence, the degree of the curves is $2n$ under all circumstances.

For the purpose of performing this development and elimination in actual cases I have calculated the numerical coefficients of the powers of $\sin nx$ and $\cos nx$ for all values of n up to 20. They accompany this paper in tabular form.

Another method of performing the elimination is to form the equation of the tangent to the curve, which is particularly easy by finding

$$\frac{dy}{dx}$$

by simple differentiation and inserting in the general equation of the tangent, and then finding the envelop of the tangent.

If for any purpose polar co-ordinates are required, they can be easily obtained by the following transformation:

(1) $x = e_1 \cos a\,wt + \text{etc.}$

(2) $y = e_1 \sin a\,wt + \text{etc.}$

$\rho \cos \vartheta = x.$

$\rho \sin \vartheta = y.$

Multiply (1) by $\cos \vartheta$ and (2) by $\sin \vartheta$ and add; we get $\rho = e_1 \cos a_1 wt \cos \vartheta + e_1 \sin a_1 wt \sin \vartheta +$ etc.

Multiply (1) by $\sin \vartheta$ and (2) by $\cos \vartheta$ and subtract; we get $o = e_1 \cos a_1 wt \sin \vartheta - e_1 \sin a_1 wt \cos \vartheta +$ etc.

Eliminating wt by any of the methods already described, we get an equation between ρ and ϑ.

In order to illustrate the beauty and variety of the curves drawn by the geometric chuck, and to render the preceding text clearer, I have drawn a number of curves which are appended to the paper.

The following is a description of the figures.

The first eighteen curves are produced by the combination of two circular motions. The equations comprising all of them are:

$x = e_1 \cos a_1 wt + e_2 \cos a_2 wt.$

$y = e_1 \sin a_1 wt + e_2 \sin a_2 wt.$

Fig. 1.	$v_1 =$	1	$a_1 =$	1	$a_2 =$	2
			$e_1 =$	1	$e_2 =$	·5
Fig. 2.	$v_1 =$	1	$a_1 =$	1	$a_2 =$	2
			$e_1 =$	·5	$e_2 =$	·8
Fig. 3.	$v_1 =$	+2	$a_1 =$	1	$a_2 =$	3
			$e_2 =$	·5	$e_2 =$	·5
Fig. 4.	$v_1 =$	+2	$a_1 =$	1	$a_2 =$	3
			$e_1 =$	·5	$e_2 =$	·8
Fig. 5.	$v_1 =$	−2	$a_1 =$	1	$a_2 =$	−1
			$e_1 =$	·5	$e_2 =$	·8
Fig. 6.	$v_1 =$	−2	$a_1 =$	1	$a_2 =$	−1
			$e_1 =$	·5	$e_2 =$	·5
Fig. 7.	$v_1 =$	+3	$a_1 =$	1	$a_2 =$	4
			$e_1 =$	·5	$e_2 =$	·125
Fig. 8.	$v_1 =$	+3	$a_1 =$	1	$a_2 =$	4
			$e_1 =$	·5	$e_2 =$	·2
Fig. 9.	$v_1 =$	+3	$a_1 =$	1	$a_2 =$	4
			$e_1 =$	·5	$e_2 =$	·3
Fig. 10.	$v_1 =$	+3	$a_1 =$	1	$a_2 =$	4
			$e_1 =$	·5	$e_2 =$	·4
Fig. 11.	$v_1 =$	+3	$a_1 =$	1	$a_2 =$	4
			$e_1 =$	·5	$e_2 =$	·5
Fig. 12.	$v_1 =$	+3	$a_1 =$	1	$a_2 =$	4
			$e_1 =$	·5	$e_2 =$	0

Fig. 13.	$v_1 = -3$	$a_1 = 1$	$a_2 = -2$	
		$e_1 = .5$	$e_2 = .1$	
Fig. 14.	$v_1 = -3$	$a_1 = 1$	$a_2 = -2$	
		$e_1 = .5$	$e_2 = .2$	
Fig. 15.	$v_1 = -3$	$a_1 = 1$	$a_2 = -2$	
		$e_1 = .5$	$e_2 = .25$	
Fig. 16.	$v_1 = -3$	$a_1 = 1$	$a_2 = -2$	
		$e_1 = .5$	$e_2 = .3$	
Fig. 17.	$v_1 = -3$	$a_1 = 1$	$a_2 = -2$	
		$e_1 = .5$	$e_2 = .4$	
Fig. 18.	$v_1 = -3$	$a_1 = 1$	$a_2 = -2$	
		$e_1 = .5$	$e_2 = .5$	

The curves shown in *Figs. 19* to *31* are formed by the composition of three circular motions. The general equations including them are:

$$x = e_1 \cos a_1 wt + e_2 \cos a_2 wt + e_3 \cos (p_3 + a_3 wt).$$
$$y = e_1 \sin a_1 wt + e_2 \sin a_2 wt + e_3 \sin (p_3 + a_3 wt).$$

Fig. 19.	$v_1 = +3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = +3$	$a_2 = 4$	$e_2 = .5$	$p_3 = 0$
		$e_3 = 13$	$e_3 = .2$	
Fig. 20.	$v_1 = +3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = -3$	$a_2 = 4$	$e_2 = .5$	$p_3 = 0$
		$a_3 = -5$	$e_3 = .3$	
Fig. 21.	$v_1 = +3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = -3$	$a_2 = 4$	$e_2 = .5$	$p_3 = 180°$
		$a_3 = -5$	$e_3 = .3$	
Fig. 22.	$v_1 = -3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 0$
		$a_3 = -11$	$e_3 = .2$	
Fig. 23.	$v_1 = -3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 15°$
		$a_3 = -11$	$e_3 = .2$	
Fig. 24.	$v_1 = -3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 90$
		$a_3 = -11$	$e_3 = .2$	
Fig. 25.	$v_1 = -3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 180°$
		$a_3 = -11$	$e_3 = .2$	
Fig. 26.	$v_1 = -3$	$a_1 = 1$	$e_1 = .5$	
	$v_2 = -3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 0$
		$a_3 = +7$	$e_3 = .2$	

Fig. 27.	$v_1 = -3$	$a_1 = 1$	$e_1 = \cdot5$	
	$v_2 = -3$	$a_2 = -2$	$e_2 = \cdot5$	$p_2 = 0$
		$a_3 = +7$	$e_3 = \cdot3$	
Fig. 28.	$v_1 = -3$	$a_1 = -1$	$e_1 = \cdot5$	
	$v_2 = -3$	$a_2 = -2$	$e_2 = \cdot5$	$p_2 = 180°$
		$a_3 = +7$	$e_3 = \cdot3$	
Fig. 29.	$v_1 = -3$	$a_1 = 3$	$e_1 = \cdot75$	
	$v_2 = -\frac{10}{3}$	$a_2 = -6$	$e_2 = \cdot4$	$p_2 = 0$
		$a_3 = +24$	$e_3 = \cdot17$	
Fig. 30.	$v_1 = -3$	$a_1 = 3$	$e_1 = \cdot75$	
	$v_2 = -\frac{10}{3}$	$a_2 = -6$	$e_2 = \cdot4$	$p_2 = 180°$
		$a_3 = +24$	$e_3 = \cdot17$	
Fig. 31.	$v_1 = -3$	$a_1 = 3$	$e_1 = \cdot75$	
	$v_2 = -\frac{10}{3}$	$a_2 = -6$	$e_2 = \cdot4$	$p_2 = 0$
		$a_3 = +24$	$e_3 = \cdot4$	

Figures 33 to 40 are curves formed by the combination of four circular motions. The general equations are:
$x = e_1 \cos a_1 wt + e_2 \cos a_2 wt + e_3 \cos (a_2 wt + p_2) + e_4 \cos (a_4 wt + p_4)$; $y = e_1 \sin a_1 wt + e_2 \sin a_2 wt + e_3 \sin (a_2 wt + p_2) + e_4 \sin (a_4 wt + p_4)$.

Fig. 32.	$v_1 = +3$	$a_1 = 1$	$e_1 = \cdot2$	
	$v_2 = +3$	$a_2 = 4$	$e_2 = \cdot5$	$p_2 = 0$
	$v_3 = +3$	$a_3 = 13$	$e_3 = \cdot5$	$p_4 = 0$
		$a_4 = 40$	$e_4 = \cdot3$	
Fig. 33.	$v_1 = +3$	$a_1 = 1$	$e_1 = \cdot2$	
	$v_2 = +3$	$a_2 = 4$	$e_2 = \cdot5$	$p_2 = 0$
	$v_3 = -3$	$a_3 = 13$	$e_3 = \cdot5$	$p_4 = 0$
		$a_4 = 14$	$e_4 = \cdot3$	
Fig. 34.	$v_1 = +3$	$a_1 = 1$	$e_1 = \cdot2$	
	$v_2 = -3$	$a_2 = 4$	$e_2 = \cdot5$	$p_2 = 0$
	$a_3 = +3$	$a_3 = -5$	$e_3 = \cdot5$	$p_4 = 0$
		$a_4 = -32$	$e_4 = \cdot3$	
Fig. 35.	$v_1 = -3$	$a_1 = 1$	$e_1 = \cdot2$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = \cdot5$	$p_2 = 0$
	$v_3 = +3$	$a_3 = -11$	$e_3 = \cdot5$	$p_4 = 0$
		$a_4 = -38$	$e_4 = \cdot3$	
Fig. 36.	$v_1 = +3$	$a_1 = 1$	$e_1 = \cdot2$	
	$v_2 = -3$	$a_2 = 4$	$e_2 = \cdot5$	$p_2 = 0$
	$v_3 = -3$	$a_3 = -5$	$e_3 = \cdot5$	$p_4 = 0$
		$a_4 = 22$	$e_4 = \cdot3$	

Sin $a = \sin a$

$2a = \cos a\,[\,2 \sin a\,]$

$3a = 3 \sin a - 4 \sin^3 a$

$4a = \cos a\,[\,4 \sin a - 8 \sin^3 a\,]$

$5a = 5 \sin a - 20 \sin^3 a + 16 \sin^5 a$

$6a = \cos a\,[\,6 - 32 + 32\,]$

$7a = 7 - 56 + 112 - 64 \sin^7 a$

$8a = \cos a\,[\,8 - 80 + 192 - 128\,]$

$9a = 9 - 120 + 432 - 576 + 256 \sin^9 a$

$10a = \cos a\,[10 - 160 + 672 - 1024 + 512\,]$

$11a = 11 - 220 + 1232 - 2816 + 2816 - 1024 \sin^{11} a$

$12a = \cos a\,[12 - 280 + 1792 - 4608 + 5120 - 2048\,]$

$13a = 13 - 364 + 2912 - 9984 + 16640 - 13312 + 4096 \sin^{13} a$

$14a = \cos a\,[14 - 448 + 4032 - 13768 + 28160 - 24576 + 8192\,]$

$15a = 15 - 560 + 6048 - 28800 + 70400 - 92160 + 61440 - 16384 \sin^{15} a$

$16a = \cos a\,[16 - 672 + 8064 - 42240 + 112640 - 159744 + 114688 - 32768\,]$

$17a = 17 - 816 + 11424 - 71808 + 239360 - 452608 + 487424 - 278528 + 65536 \sin^{17} a$

$18a = \cos a\,[18 - 960 + 14784 - 101376 + 366080 - 745472 + 860160 - 524288 + 131072\,]$

$19a = 19 - 1140 + 20064 - 160512 + 695552 - 1770496 + 2723840 - 2490368 + 1245184 - 262144 \sin^{19} a$

$20a = \cos a\,[20 - 1320 + 25344 - 219648 + 1025024 - 2795520 + 4587520 - 4456448 + 2359296 - 524288\,]$

Cos $a = \cos a$

$2a = 1 - 2 \sin^2 a$

$3a = \cos a\,[1 - 4$

$4a = 1 - 8 + 8 \sin^4 a$

$5a = \cos a\,[1 - 12 + 16\,]$

$6a = 1 - 18 + 48 - 32 \sin^6 a$

$7a = \cos a\,[1 - 24 + 80 - 64\,]$

$8a = 1 - 32 + 160 - 256 + 128 \sin^8 a$

$9a = \cos a\,[1 - 40 + 240 - 448 + 256\,]$

$10a = 1 - 50 + 400 - 1120 + 1280 - 512 \sin^{10} a$

$11a = \cos a\,[1 - 60 + 560 - 1792 + 2304 - 1024\,]$

$12a = 1 - 72 + 840 - 3584 + 6912 - 6144 + 2048 \sin^{12} a$

$13a = \cos a\,[1 - 84 + 1120 - 5376 + 11520 - 11264 + 4096\,]$

$14a = 1 - 98 + 1568 - 9408 + 26880 - 39424 + 28672 - 8192 \sin^{14} a$

$15a = \cos a\,[1 - 112 + 2016 - 13440 + 42240 - 67584 + 53248 - 16384\,]$

$16a = 1 - 128 + 2688 - 21504 + 84480 - 180224 + 212992 - 131072 + 32768 \sin^{16} a$

$17a = \cos a\,[1 - 144 + 3360 - 29568 + 126720 - 292864 + 372736 - 245760 + 65536\,]$

$18a = 1 - 162 + 4320 - 44352 + 228096 - 658944 + 1118208 - 1105920 + 589824 - 131072 \sin^{18} a$

$19a = \cos a\,[1 - 180 + 5280 - 59136 + 329472 - 1025024 + 1863680 - 1966080 + 1114112 - 262144\,]$

$20a = 1 - 200 + 6600 - 84480 + 549120 - 2050048 + 4659200 - 6553600 + 5570560 - 2621440 + 524288 \sin^{20} a$

Fig. 37.	$v_1 = -3$	$a_1 = 1$	$e_1 = .2$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 0$
	$v_3 = -3$	$a_3 = -11$	$e_3 = .5$	$p_4 = 0$
		$a_4 = 16$	$e_4 = .3$	
Fig. 38.	$v_1 = -3$	$a_1 = 1$	$e_1 = .2$	
	$v_2 = +3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 0$
	$v_3 = -3$	$a_3 = -11$	$e_3 = .5$	$p_4 = 0$
		$a_4 = 16$	$e_4 = .2$	
Fig. 39.	$v_1 = -3$	$a_1 = 1$	$e_1 = .2$	
	$v_2 = -3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 0$
	$v_3 = +3$	$a_3 = 7$	$e_3 = .5$	$p_4 = 0$
		$a_4 = 34$	$e_4 = .3$	
Fig. 40.	$v_1 = -3$	$a_1 = 1$	$e_1 = .2$	
	$v_2 = -3$	$a_2 = -2$	$e_2 = .5$	$p_3 = 0$
	$v_3 = -3$	$a_3 = 7$	$e_3 = .5$	$p_4 = 0$
		$a_4 = -20$	$e_4 = .3$	

WIRELESS MESSAGES TO A MOVING TRAIN.

On the occasion of the recent Forty-seventh Annual Convention of the American Association of General Passenger and Ticket Agents, the Grand Trunk Railway gave a demonstration of wireless telegraphy on a moving train. The experiment was entirely successful.

The demonstration was made by Dr. E. Rutherford, F.R.S.C., and Dr. Howard T. Barnes, F.R S.C., both of the Macdonald Physical Laboratory of the McGill University, Montreal. Signals were exchanged between a station and a train (which was running at the rate of 50 miles an hour). No attempt was made to cover distances comparable in length with those attained by Marconi and others, but with comparatively simple laboratory apparatus it was possible to keep the train in touch with the station for from 8 to 10 miles. St. Dominique was selected as the transmitting station, where two large metal plate vibrators 10 x 12 feet, connected with an induction coil of the usual pattern, were situated. On the train itself the waves were received by collecting wires connected to a coherer of nickel and silver powder. The relay operated electric bells in three cars. The collecting wires were run through the guides for the train signal-cord, and extended on both sides of the coherer for about one car length. To obtain the maximum effect it would have been better to have had a long vertical wire, but since this was impossible, the horizontal wire was used. Although these were placed *inside* the steel frame cars, strong and definite signals were obtained over the distance named. Another difficulty militated against obtaining the maximum sensitiveness, as owing to the natural vibration of the train resulting from its great speed, it was impossible to have the relay adjusted to its most sensitive point. In spite of these difficulties the distance to which signals could be sent to the train was eminently satisfactory, and with more refined apparatus greater distances could, without doubt, be covered. The success of this form of wireless telegraphy, of which this was but a pioneer experiment, opens up yet another method of providing for the safety of the traveling public.—*Scientific American.*

PHYSICAL SECTION.

Stated Meeting, held Thursday, January 15, 1903.

A Relation between the Mean Speed of Stellar Motion and the Velocity of Wave Propagation in a Universal Gaseous Medium Bearing upon the Nature of the Ether.

By Luigi d'Auria.

In the *Philosophical Magazine* for August, 1901, Lord Kelvin pointed out that an infinite ether must of necessity be *imponderable;* that is, a substance outside the law of universal gravitation, leaving the alternative, however, that a gravitational ether may be admitted, occupying only a finite volume of space. Such an ether could exist only as an immense gaseous globe, and if w denotes the density of this globe at any distance z from the center; w_0 the mean density of the concentric sphere of elementary gas of radius z; S the distance which separates the solar system from the center of the universal gaseous globe; σ the density of the gas in this system; k the constant of gravitation; then, on the supposition that the gaseous globe is in equilibrium of temperature, so that the mean square speed u of the elements of matter throughout its volume is constant, we would have the equation

$$\tfrac{1}{3} u^2 \, d \, w = \tfrac{4}{3} \pi z^2 w_0 \times \frac{k \, w \, d \, z}{z^2},$$

or

$$\frac{d \, w}{w \, w_0} = \frac{4 \pi k}{u^2} z \, d \, z. \quad (1)$$

In order to find a relation between w and w_0, assume that w varies inversely with some power n of the distance; that is, put

$$w = \sigma \left(\frac{S}{z}\right)^n. \quad (2)$$

Then, the mass of a concentric spherical shell of gas of thickness dz and radius z can be expressed by

$$4\pi\sigma\left(\frac{S}{z}\right)^n z^2\,dz,$$

and therefore we can put

$$\tfrac{4}{3}\pi z^3 w_0 = 4\pi\sigma\int_0^z \left(\frac{S}{z}\right)^n z^2\,dz,$$

from which

$$w_0 = \frac{3}{3-n}\sigma\left(\frac{S}{z}\right)^n = \frac{3w}{3-n}. \quad (3)$$

Substituting this in (1) we can write

$$\int\frac{dw}{w^{\frac{n}{n}}} = \frac{3}{3-n}\times\frac{4\pi k}{u^2}\int z\,dz,$$

which gives

$$w = \frac{3-n}{6\pi k}\cdot\frac{u^2}{z^2}. \quad (4)$$

Comparing this expression for w with (2), we can easily conclude that $n = 2$, and therefore

$$w = \sigma\left(\frac{S}{z}\right)^2, \quad (5)$$

which shows that the density in the gaseous globe would not be uniform, but would vary inversely as the square of the distance from the center.

Substituting $n = 2$ in (3) and (4), we get

$$w_0 = 3w; \quad (6)$$

$$w = \frac{u^2}{6\pi k z^2}; \quad (7)$$

and comparing (7) with (5), we get

$$\sigma = \frac{u^2}{6\pi k S^2} \quad (8)$$

and

$$u^2 = 6\pi k S^2\sigma. \quad (9)$$

The mass of a concentric sphere of gas of radius s would be

$$\tfrac{4}{3}\,\pi\, s^3\, w_0 = 4\,\pi\, s^3\, w,$$

and observing that (5) gives $s^2\, w = S^3\,\sigma$, we can write

$$\tfrac{4}{3}\,\pi\, s^3\, w_0 = 4\,\pi\, S^2\, s\,\sigma.$$

Hence, the attraction of this sphere upon a unit mass at its surface would be

$$\varphi = \frac{4\,\pi\, k\, S^2\,\sigma}{s}. \quad (10)$$

Now, the centrifugal force which a unit mass acquires revolving with velocity v_0 in a circular orbit of radius s is v_0^2/s. Putting this equal to φ, we get

$$v_0^2 = 4\,\pi\, k\, S^2\,\sigma. \quad (11)$$

As this is independent of the distance s, we can conclude that all bodies moving in circular orbits around the center of the universe must have the same velocity.

Comparing (9) with (11), we get the simple relation

$$u^2 = \tfrac{3}{2}\, v_0^2. \quad (12)$$

Denoting by V the speed of propagation of a wave in the universal gaseous medium, we have also

$$V^2 = \tfrac{1}{3}\,\gamma\, u^2,$$

and putting $\gamma = 5/3$,

$$V^2 = \tfrac{5}{9}\, u^2. \quad (13)$$

Substituting for u its value (12), we get

$$V^2 = \tfrac{5}{6}\, v_0^2. \quad (14)$$

This relation shows that the speed of wave-propagation in a universal gaseous medium is not much greater than the velocity v_0, which velocity would be approximately equal to the mean speed of stellar motion. This, according to Kapteyn's investigation, appears to be about 19·3 miles per second, and therefore, according to our relation (14), the speed of wave-propagation in a universal gaseous medium could not be much greater than 17·6 miles per second.

This shows that such a medium would be utterly unfit to propagate energy with the velocity of light, and proves conclusively that the ether must be imponderable; that is, a substance outside the law of universal gravitation, whether the ether be infinite or finite.

Denoting by R and D the mean radius and the mean density of the earth, and by g the acceleration of gravity at the earth's surface, we can write

$$k = \frac{3\,g}{4\,\pi\,R\,D}$$

and substituting this in (8) and putting for u its value (12), we get

$$\sigma = \tfrac{1}{8}\,\frac{R\,D}{g}\left(\frac{v_0}{S}\right)^2. \quad (16)$$

If a plausible value could be assigned to S in this formula, then with the approximate value $v_0 = 19{\cdot}3$ miles per second, we could form an idea of the density which a universal gaseous medium would have in the solar system. Now, on the assumption of such a medium we would, according to our law of density (5), naturally expect to find the central regions of the universe occupied by a gas of considerable density, which would give us valid ground for assuming that in such regions only could the astonishing phenomena observed in *Nova Persei* take place. On this assumption we might use the distance of this star for the value of S, a distance which has been recently estimated to be about 159 light years, or $9{\cdot}36 \times 10^{14}$ miles.

Using this value for S and putting for R, D and g their numerical values, we get approximately

$$\sigma = 3{\cdot}9 \times 10^{-19}\,d, \quad (17)$$

in which d is the density of ordinary air. We have here a density which is of the same order of magnitude as that of ether, and which cannot be changed to any great extent by any reasonable change made in the values of S and v_0 assumed above. Indeed, we have good reasons to suppose that the solar system is rather near the center of the Milky

Way, and as this center would, according to our hypothesis, coincide with the center of the universe, the distance of 159 light years assumed for S is not too great, nor can it be very much smaller. Hence, the value of σ cannot deviate much from the value (17) and therefore there cannot be any objection raised against our hypothesis of a universal gaseous medium on the ground that it would oppose appreciable resistance to the motion of planets or other celestial bodies. It is true that the density of such a medium would be quite considerable in the vicinity of the center of the universe, but a simple calculation based upon our formula (16) will show that we would have to be within 585,000 miles of this center to find a density equal to that of ordinary air. The concentric sphere of the medium within a radius of 585,000 miles would have a mass about seven times that of the planet Jupiter, a mass entirely too small to be conspicuous in celestial space.

THE RUTHENBERG PROCESS AT LOCKPORT.

On Thursday, January 15th, a party of iron manufacturers visited the plant of the Cowles Electric Smelting and Aluminum Works at Lockport, N. Y., where there is installed what is erroneously called an electrical furnace. The apparatus is the invention of Marcus Ruthenberg, of Philadelphia, and really is capable of performing two functions—that of agglomerating or fritting fine ores, concentrates or flue-dust so as to put them into much better condition for charging into the blast furnace, or that of reducing the iron oxide to what may be termed a sponge, to be employed as a raw material in the open-hearth furnace. The apparatus consists of a horizontal horseshoe magnet hinged so that its poles may be approached. The poles are surrounded by water-cooled bronze rolls covered with carbon plates, which rotate in opposite directions. Along the lines of closest approach an electric arc is formed which subjects the material to be operated upon to a high temperature. The material is fed upon one of the rolls and is thus carried to the active zone, dropping out of the reach of its influence as the revolution of the roll carries the material beyond it.

The test of the apparatus last week was witnessed by John Fritz, of Bethlehem, Pa.; S. T. Wellman, of the Wellman-Seaver-Morgan Engineering Company, Cleveland, O.; W. J. Taylor, of the Taylor Iron and Steel Company, High Bridge, N. J.; Edwin Thomas, of Catasauqua, Pa.; J. K. McLanahan, of Hollidaysburg, Pa.; Frank Slocum, of the Jones & Laughlin Steel Company, Pittsburg, Pa., and J. B. Kraemer, of the Kittanning Iron Works.

A number of experiments were made. Among them was one with Lake Champlain magnetite concentrates, both alone and with an admixture of cast borings. When the ore does not possess magnetic properties to a certain degree Mr. Ruthenberg uses cast-iron borings in order to create the arc, the percentage varying with the circumstances. When putting the ore through the machine alone the action is sluggish and the capacity suffers. The result of this operation is a fritted material which is in much better shape mechanically for charging into the blast-furnace than the crude ore. Mr. Ruthenberg makes the important point that during the exposure of the ore to the action of the electric arc a considerable part of any sulphur in the ore is eliminated.

A somewhat more interesting operation is the direct reduction of iron-ore in the electric arc. The fine ore is mixed with carbon in a suitable form, and if desirable cast-iron borings are also added. Exposure of the mixture in the electric light causes a reduction of the iron oxide and there drops from the rolls a coarse, partly sintered material, which is largely iron in metallic form. This product is employed in the place of scrap in the open-hearth furnace, one charge having been made with it at a leading steel plant.

The rated capacity of the machine at Lockport is about 2½ to 3 tons of material per day of twenty hours, but we understand that a larger machine, with rolls three times as long, is being built which it is expected will reach a capacity of 10 tons per day. The electrical energy required for the Lockport machine is about 25 horse-power.—*Iron Age.*

THE USE OF OIL IN SMELTING.

The development of the oil industry has proved very beneficial to California, which, possessing no coal-fields of her own, has always been dependent upon Australia, Wyoming, Vancouver and Japan for her supply of the fuel employed in manufacturing and smelting. In its application to smelting the use of crude oil is a comparatively new departure. At the Selby works Mr. Alfred Von der Ropp has been very successful in this direction. He finds that a matting furnace, which ordinarily requires 1 ton of coal for every 3½ tons of ore, will smelt a ton of ore per barrel of oil, so that 3½ barrels of oil are the smelting equivalent of 1 ton of coal, in a locality where coal costs $6 per ton and fuel oil 80 cents per barrel. Under the prevailing conditions the use of oil represents an economy of 50 per cent.

Besides this economy of first cost, the oil fuel has been found advantageous because the oxidizing atmosphere of a roasting furnace can be maintained without those interruptions which take place when fresh coal is added—interruptions which are accompanied by the introduction of reducing gases which temporarily cause the process of oxidation to remain at a standstill. Moreover, it is possible with oil, by regulating the air inlet of the furnace, to control the smelting atmosphere so as to obtain oxidizing or reducing conditions, as the metallurgist may desire. The ability to increase the temperature of a metallurgical operation with notable ease is another good feature. It is an interesting example of adaptation to conditions, and the readiness with which it has been used is typical of that progressiveness which characterizes the energetic people of the West.—*Engineering and Mining Journal.*

THE FRANKLIN INSTITUTE.

A lecture delivered before the Franklin Institute and the Central Branch of the Young Men's Christian Association, Friday, November 21, 1902.

Two Years in Argentine as the Consulting Engineer of National Public Works.*

By Elmer L. Corthell, Sc.D.

Mr. Chairman, Ladies and Gentlemen: When, in the development of my program for about thirty-six lectures on Argentine to be given this coming winter and spring, I found it possible to select Philadelphia as the city in which to deliver the first of this series, I was very much pleased, for three reasons:

(1) Because it would be given before the Franklin Institute. I have always remembered with much satisfaction the lecture I gave about sixteen years ago before this Institute, and the appreciative and interested audience on that occasion.

(2) Because, being a founder and a sustaining member of a new branch of the Young Men's Christian Association recently established in Buenos Ayres, I was glad to know that this lecture is to be before an audience in which the Y.M.C.A. of Philadelphia would form a part jointly with that of the Franklin Institute.

(3) Because Philadelphia, as a city, and through its active association of manufacturers and commercial men, particularly through its Museum, has done and is doing more to open foreign markets to this country and promote reciprocal trade with other countries than any city in the United States.

In 1899 the Argentine Government, having conceived an extensive project of river and harbor improvement and made the preliminary surveys, requested the U. S. Govern-

* The lecture was profusely illustrated with the aid of lantern photographs.

ment to recommend an engineer who would come to Argentine and assist the Government by his advice in forming and executing the plans.

I had the honor of being selected for this position. After carrying out a two-years' contract with that Government, I have returned to my own country with some knowledge of the conditions and some experience in meeting them, which form the basis of this lecture.

At the final general session of the International Navigation Congress at Düsseldorf, July 4th, this last year, when called upon to respond for the Argentine Republic, I used the following words:

"It may not be out of place to make a few comparisons between the two countries, which by a singular coincidence I have the honor to represent—one as a delegate to this Congress, the other as a member of the Permanent International Commission. One of these countries is the Argentine Republic, and the other the United States of North America.

"Both are cosmopolitan; both have been populated largely from Europe; both had the task of supplanting savagery by civilization. The red races in each case had to give way to the Caucasian, or be assimilated with it. Both have great plains and immense river systems. The greatest river valley of the one is almost exactly equal to that of the other. Similar causes have produced nearly similar hydraulic conditions in each case. Both countries have temperate climates; both great mountain ranges; both some extent of arid lands and running waters for irrigation; both immense areas of rich soils, made so by similar beneficent causes; both have extensive pasture lands and millions of cattle, sheep and horses. In their cereals they are competitors with each other in the food markets of Europe—one is great and ambitious; the other, smaller, but earnestly devoted to progress, and ambitious to fulfil its high destiny among the nations of the earth."

By comparisons of the unknown with the known we appreciate and learn, and for that reason I shall compare Argentine with the United States in respect to some of its

more important features, and you will see that the two great countries have much in common.

You must, if possible, imagine yourselves in a situation exactly opposite from yours in the United States in regard to the sun and the poles of the earth; you must look north for warm winds and south for cold ones. Your winter will begin in June and your summer in December. The north side of your house will be sunny and the south side in the shade. As you travel north from Buenos Ayres, the capital, it will grow warmer; as you go south you will at last reach the glaciers. Your North Star will be changed to the Southern Cross, and in all these changes you will at first be lost. You must also locate yourself geographically, and recollect that the northern line of Argentine is in about the same latitude south of the Equator as Havana is north of it, and that the southern limit of Argentine corresponds to Labrador and Kamscatka, and that Buenos Ayres, Capetown and Melbourne are all in about the same latitude. Also that there are east and west differences. Buenos Ayres is in about the same longitude as Cape Breton Island, east of Nova Scotia; and the circle of longitude along the most westerly boundary of Argentine nearly passes through New York City, and the course from the entrance of the River Plata to Liverpool is nearly a straight line. In order that the location of Argentine in reference to other South American countries may be appreciated, it should be stated that Buenos Ayres is as far south of, say, Caracas, the present center of revolutionary and unstable South America, as the north end of Lake Winnipeg, in Manitoba, is north of Caracas, or as far as the northern part of Greenland is north of New Orleans.

With this orientation of ourselves on the Western Hemisphere, and with these remarkable differences in position, let me call your attention to a very remarkable similarity wherein will be seen and appreciated the beneficent work of the Great Creator long before at least the present race of mankind inhabited the two continents.

In a paper read before the American Association for the Advancement of Science, at Buffalo, August 5, 1896, upon

the delta of the Mississippi, I described the ancient conditions of that great river in substance as follows:

(1) A deep shore-line of the Gulf of Mexico when the site of Galveston was far out in the waters and the coast was 100 miles inland from the site of New Orleans—a wide and deep estuary 1,000 miles long, reaching into the heart of the continent to between St. Louis and Cairo, where, at Cape Giradeau, it met the ridge of the Ozark Mountains, stretching across the valley and holding back the ancient great lake, which covered Chicago 100 feet deep and spread over all the Prairie States and received and distributed over its bed the immense sediments of the Missouri and other great rivers in the North. (2) The cyclic change, lifting Florida out of the water and turning continental drainage north, cutting its way through the alluvion to Hudson Bay. (3) The breaking down of the Ozark barrier; the draining of the submerged area; the subsequent filling of the estuary and the advance of the alluvial lands into the Gulf to their present line, 110 miles beyond New Orleans. A great and wonderful beneficence for the use and convenience of man by the Great Architect of the universe.

Had not my engineering experience upon the Mississippi River and its delta drawn my attention to this extremely interesting ancient history of the great river of North America, I might not have been so deeply impressed by its remarkable similarity with that of the Paraná River in South America; and for both histories I am indebted to engineering investigators: General Warren, in the first instance, and Col. Geo. Earl Church, an American engineer living in London, in the second instance, the latter probably better acquainted by personal contact with the geography and hydraulics of south America than any living man.

I am indebted to him and the Royal Geographic Society, of which he is a director and a correspondent, for most of what follows in relation to this *ancient* history of the great rivers of Argentine and Central South America.

There are four great breaks in the mountained-fringed continent which we may call its great commercial doorways: The Orinoco, the Amazon, the La Plata and the deep inden-

tation of Bahia Blanca—one in Venezuela, one in Brazil and two in Argentine. The three river basins occupy two-thirds of the entire area of South America.

The two with which we are most interested in this lecture are the La Plata and Amazon, which have areas respectively of about 1,200,000 square miles and 2,722,000. But if we deduct from the latter the valley of the Tocantins, which has no direct connection with it, the valley of the Amazon is only 2,368,000 square miles, of which its principal branch, the Madeira, has a volume of discharge nearly equal to the Amazon itself, and at the falls, which I shall refer to later, it carries annually a volume equal to that of the La Plata, which has a minimum flow of about 534,000 cubic feet per second and a maximum of over 2,000,000—a river nearly double the size of the Mississippi (the Father of Waters), if we compare their mean annual discharges, the former being about 288 cubic miles and the latter 156 cubic miles. The Paraná ("the Mother of the Sea" in Indian language), the principal affluent of the La Plata, is itself 46 per cent. larger than the Mississippi, its mean annual discharge being about 230 cubic miles.

What a river the La Plata must have been in ancient times, when it had a maximum discharge of 4,000,000 cubic feet per second, well up toward the modern Amazon, estimated to be 5,297,000, and greater than the ancient Amazon!

I have described the ancient conditions of the Mississippi; the Gulf of Mexico as a great estuary and a deep shoreline extending well into the heart of the North American Continent. The same conditions existed in the contour line of South America in the La Plata estuary. It extended 1,400 miles into the continent and was 400 miles wide—eleven times greater than the Empire State. It was the great Pampean Sea, receiving the drainage not only of the present Paraná and its tributaries, but of the great Madeira River with its immense discharge of waters and sedimentary matters, the source of great alluvial formations, discharging into a sea two-thirds the size of the Mediterranean.

When, in the processes of Nature, the great underwater plains of rich soil had been formed during the comparatively

short period of less than 100,000 years, a dam was thrown across the Madeira by the rivers Grande and Parapití coming down from the Andes, and a deposit of more than 170 feet deep occurred, forming this dam, which produced the ancient Lake Mojos, with an area of about 115,000 square miles—larger than that of the great lakes of North America combined, which is less than 94,000.

The remarkable action of these rivers and the changes caused by it are graphically told by Colonel Church in his paper upon "Argentine Geography and the Ancient Pampean Sea."

"The Grande and the Parapití entered the plain with a northern trend to contest with the great river of the north the possession of the gap. They struck it almost at a right angle, and slowly pushed their rival eastward over against the Chaco base of the Chiquitos Sierras. Here the final conflict must have taken place, as the Grande and Parapití threw their dam across the outlet of the Mojos River, thus cutting off its exit into the ancient sea. No doubt the giant stream waged fierce war for thousands of years to keep its channel open, alternately sweeping away the barrier and again yielding to the ceaseless volume of sand and clay, which, visible to-day, confirms the victory of the Grande and Parapití. The dam having finally become permanent, the formation of the ancient Mojos Lake was assured. When it reached the level of the lip of Guajará-mirim, its waters commenced to tumble over it and carve their way to the Amazon. Since then, huge volumes of alluvium have poured down the northern slopes of the Bolivian Andes. The ancient lake is now almost loaded with material, but is not yet entirely obliterated. The muddy silt which covers the surface of the basin is so fine, that when an Indian goes up-stream to the mountains his friends ask him to bring back a stone that they may see what it is like.

"Since forming the dam, the Rio Grande has slowly been returning westward down the counterslope which its own alluvium creates."

During the process we have described, the ancient lake

and the Pampean Sea were connected, and their relation was similar to that of the Black Sea and Mediterranean. Traces of it are still observable, notably the great low-flooded morass of Xarayes on the upper Paraguay River, and the ancient delta of the Paraná, including the Ybará lagoon. The Salina Grande was also an arm of it—a great inland fiord. The sea, moreover, must have covered large areas of Paraguay, Corrientes, Entre Rios and Uruguay, and before the uplifting of the country it extended southwest to the rivers of Chadi-Leofu and the Colorado, lapping round the southern slope of the Ventana Range, until the curved rim, concave to the northeast, which connects this with the Sierra de Cordova, was sufficiently elevated to completely cut off its southwestern extension.

This range was high enough to lodge the glacial rocks coming from the Andes, one of which at Tandil is so poised and delicately balanced that the hand can rock it, but it cannot be dislodged. This range later prevented the entrance of the destructive sea, protecting the great area from its waves.

Then came another factor into the beneficent problem of the Creator. Instead of draining the waters from the great deposits under the Pampean Sea, as He did in North America, He lifted the Andes higher, and with them their atlantic slopes, until the latter were ultimately lifted to their present level, forming the "Plains of the Pampas," the soil of which is 50 feet deep and of surpassing richness —an area of 600,000 square miles—one-fifth the size of the United States and five times that of Great Britain. Thus by cyclic changes in the Northern Hemisphere, and by fluvial and sedimentary action and seismic changes in the Southern Hemisphere, have been formed the great interior agricultural regions of the United States and Argentina.

Let me now quote from Mr. Revy's work on "Hydraulics of Great Rivers" (Argentine rivers which he surveyed) where he compares the rivers as we now find them with others well known.

"Great as the volume of the Paraná River at its lowest summer level is—immense in comparison to the largest

European river, and much larger than that of all the European rivers put together—it is but a small fraction of its flood-volume during exceptional rises; and we can only wonder at the magnitude of the sources, which for months, nay, for whole years together pour forth inconceivable masses of sweet water, every drop of which had been raised by the power of the sun from the Pacific and Atlantic Oceans above the tops of the highest mountains of Brazil and the Andes.

"To convey an idea of the magnitude of the rivers which have been considered and analyzed in the preceding chapters, we have shown on Plate V several of the larger known rivers, such as the Danube and Thames of Europe, and the Mississippi of North America. They are all drawn to the same scale, and their relative size may somewhat be appreciated. The Mississippi is not unlike the Uruguay in dimensions and other features—we have similarity in width, depth, currents and fall, although the North American is the larger of the two. Comparing, however, the Paraná with the Mississippi, the former might claim the latter as his eccentric daughter under fourteen. The low-water dimensions measure a river's greatness, although things of different natures and character do not bear strict comparison. What we, however, understand by greatness is possessed in an exceptional degree by the Paraná."

In order, further, to compare the Paraná River with others, it may be stated that its annual flow is double that of the Ganges, three times that of the Saint Lawrence, four times that of the Danube and five times that of the Nile. We have records of *608 cubic miles* in one year; the mean being 288 and that of the Mississippi 156.

There are differing conditions of importance between the Paraná and the Mississippi, explaining the causes of the greater discharge of the Paraná. While they both flow south, one flows from colder to warmer, and the other from warmer to colder regions; and it is in the warmer regions in both cases that the rainfall is the greater. On the Mississippi, in the northern regions, where we find the greatest drainage area, the rainfall is about 35 inches per annum; in

the southern, where the area is less, the rainfall is 60 inches per annum. With the Paraná there is a rainfall of about 60 inches in the northern part, where the drainage area is greater, and about 40 inches in the southern part, where it is less.

The length of the Paraná River is about 3,000 miles; its navigable length, between Cuyabá in the north and the mouth of the Paraná in the delta of the La Plata, is 1,825 miles. The Uruguay River, from San Javier to the delta of the La Plata, has a navigable length of 603 miles. The Paraná River is made up of the two important rivers which unite at the city of Corrientes: the Paraguay and the Alto Paraná. The length of the latter above Corrientes, to the falls of the Iguazú, is 365 miles, and it is navigable nearly to that point. These wondrous falls excel in beauty, as well as exceed in dimensions, the Niagara Falls.

The latter are 160 feet high and four-fifths of a mile long, including Goat Island. The Iguazú are 213 feet high in one leap and 106 feet each in two leaps, and 2⅛ miles long with, at times, an immense volume of water.

The view before you is from a painting by a well-known Bern painter, Mr. Methfessel, who was engaged to come to Argentine, visit the Falls and make a large painting for the La Plata Museum.

The gorgeous and varicolored foliage of the luxuriant subtropical vegetation, which abounds on all sides, adds a charm to the Falls. They rank among the most beautiful and wonderful works of the Creator.

The remolinos, or whirlpools, below the Falls equal the famous whirlpool at Niagara.

The Uruguay is an entirely different river, in every respect, from the Paraná. It is at times a mighty river rivaling the Paraná; at others, it sinks into comparative insignificance. The Paraná is a great river at all times.

"The Paraná is a type of a truly great river; the Uruguay represents a mighty torrent of extraordinary dimensions."

The Uruguay rises near the Atlantic Seaboard in Brazil, in the Sierra del Mar, then runs west to the highlands of the

territory of Misiones. These highlands prevent it from uniting with the Alto Paraná River at that point, which is only about 68 miles distant. Along 600 miles of its course, from San Javier to Concordia, the bed of the river is filled with rocky ridges which, at low water, prevent any navigation, but during the floods, which are quite sudden but not long continued, the river is everywhere navigable. The river rises in floods at Concordia about 46 feet. Compared with the Paraná, it is a clear stream, carrying very little sediment in suspension. The Paraná is an entirely different river. Its source being in the tropical and rainy region of Brazil, on the flanks of the Andes, its floods are much longer continued. At the confluence of the Paraná and the Alto Paraná, at Corrientes, the rise of the floods is about 33 feet; at Rosario, 225 miles above Buenos Ayres, it is from 19·7 to 23 feet or 23½ feet in extreme floods. When these occur, the river is about 23 miles wide, covering the entire country with a depth of 6½ to 10 feet.

The physical characteristics of the bed of the river are, consequently, entirely different from those of the Uruguay; the bed of the latter is stable, that of the former very unstable. The sedimentary matters carried in suspension, however, are very much less than those of the Mississippi; probably only one-tenth of the amount carried in the Mississippi in times of flood. For this reason, the changes in the bed and banks are less radical; the most notable change is the movement of the islands and bars down-stream. For example, the Island of Espinillo, in front of the City of Rosario, lying in the middle of the river and about 2½ miles long, has moved flanking down-stream about 2½ miles in the last fifty years, and by this movement the advancing bar of the island has approached the river bank in front of Rosario and closed up the navigation channel.

The maximum velocity in great floods often reaches 6½ feet per second, although usually it is much less.

Both rivers are susceptible of improvement by dredging, the one to Asunción, which is 842 miles above the mouth, and the second to Concordia, which is 230 miles above its mouth. In the Paraná there is nothing but sand to be

removed throughout its entire length; in the Uruguay there are several places where it is necessary to remove rock and gravel. But, generally, the channel can be deepened by hydraulic or suction dredging.

The National Government is under obligation, by the law passed by Congress for building the Port of Rosario, to make and maintain a depth of 21 feet at low water in the Paraná River from the head of the Delta to Rosario, and in the Delta of the La Plata to Buenos Ayres, a depth of 19 feet at low water, which is about 21 feet at mean high tide. It has been proposed to make and maintain a channel of the following dimensions: From the mouth of the two rivers at the Island of Martin Garcia, at the head of the La Plata estuary, to Rosario, a depth of 21 feet and a width of 328 feet; Rosario to Santa Fé, 292 miles above Martin Garcia, 19 feet deep and 328 feet wide; Santa Fé to Corrientes, 10 feet deep. Santa Fé, or its seaport Colastiné, is the head of ocean navigation; above that point it is river navigation by steamboats.

On the Uruguay River it is proposed to make a channel 19 feet deep and 328 feet wide, from Martin Garcia to Concepcion del Uruguay, 137 miles above Martin Garcia, and thence 15 feet deep to Colon, and 9 feet deep and 8 feet over the rock to Concordia, which is 230 miles above Martin Garcia.

The low-water plane, or zero, in both rivers is that of extraordinary low water, so that, generally, the low water does not reach this plane within about ½ a meter to 1 meter; consequently, there can generally be depended upon from 2 to 3 feet more water than I have stated. Between Rosario and Buenos Ayres there are now no bars over which there is not 21 feet of water at 0, although two of them need to be dredged and buoyed in order to make a straighter channel. This the Government is prepared to do.

As to the port of Rosario, a contract has recently been made under the law of Congress to make a modern seaport at this point, with all the latest and best facilities for handling cargo. The commerce of Rosario is at present 1,500,000 tons per annum. It is a very important exporting point for

cereals, and when the port is completed, according to the plans adopted, it is expected to be an important importing port as well. There are ports below Rosario, such as Villa Constitución, San Nicolas and San Pedro, and above Rosario, Diamante, Santa Fé, Colastiné and Paraná. On the Uruguay River, Concordia, at the head of steamboat navigation, is an important importing and exporting place for that section of the country. Its registered tonnage is about 500,000 tons, and the actual weight tonnage about 100,000.

The country between the Paraná and Uruguay Rivers is practically isolated from the rest of the country, and its situation is very similar to the country lying between the Euphrates and the Tigris; for that reason it has been called the "Mesopotamia Argentina."

There are at present in that area three railroad systems—the Argentine Northeastern, which runs from Corrientes, on the Paraná, to Monte Caseros, on the Uruguay, and from there to Santo Tomé on the same river; the Argentine Eastern from Monte Caseros to Concordia; and the Entre Rios Railroad, the main line of which connects Paraná and Concepcion del Uruguay, with branches to Victoria, Gualeguay, Gualeguaychú and Villaguay. Within a few months a connecting line will be extended to Concordia, forming a link between the Argentine Eastern and the Entre Rios Systems. It has been proposed to unite these three systems and to extend the Argentine Northeastern from Santo Tomé to Posadas on the Alto Paraná, passing through the colonies which the Government is establishing in that territory. Posadas is its capital. The Central Paraguayan Railroad, which runs in a southeasterly direction from Asunción, it is proposed to extend to Villa Encarnación, a small town on the opposite side of the river from Posadas; to change the gage, which is 5½ feet, to the normal gage of the other three railroads, which is 4 feet 8½ inches; make a transfer by car float at Posadas; extend the Entre Rios Railroads to a port of deep water, either on the Paraná or Uruguay, and do a "through" business between Asunción and this new seaport, which will be only a few hours distant from Buenos Ayres.

With the Paraná River improved to Asunción, and the Uruguay improved to Concordia; with the railway systems united and extended to a good seaport, this great interior district of the country will have an ideal system of transportation, and the shipper can take his choice to ship by rail or by water, thus establishing a very useful and reasonable competition between water and railway, to the great advantage of the people.

In reference to the Rio de la Plata itself, it is an immense shoal estuary. It is the depositing ground of the great Paraná River. This estuary, in a not very remote period, extended above Santa Fé; this is shown by the comparison of old maps, of which ninety-two have been collected and copied and placed in the Library of the Ministry of Public Works. These maps date from the year 1529 to 1885. Even in this comparatively short period, remarkable changes are shown in the Delta of the Paraná, which is now a true delta, almost exactly in the form of the Greek letter *Δ*. It is 40 miles across its face; it slowly extends itself in the head of the estuary, and through the delta nearly a dozen outlets of the Paraná River find their way. It is very much like the deltas of the Danube, Ganges and Mississippi.

The superficial extension of the Rio de la Plata exceeds 18,000 square miles—larger than Switzerland; it is about 186 miles long and varies in width from 186 miles at the ocean, between Capes San Antonio and Santa Maria, to 1·12 miles at the extreme point of the head of the estuary, at Punta Gorda.

To understand the physical conditions of the estuary, it is necessary to divide the Rio de la Plata into Superior and Inferior, or upper and lower. The Rio de la Plata Superior lies above a line extending between La Plata and Colonia, the Inferior below that line to the sea. Over a distance of about 25 to 30 miles between Martin Garcia and the anchorage of Buenos Ayres, there is a normal depth through the best channels of from 16 to 20 feet at low water.

The National Government has recently completed the dredging over the San Pedro bar lying in this region,

increasing the depth of 18½ feet to 21 feet, where there was formerly only 15 feet. In the Canal de las Limetas, or Nuevo Canal, by the natural forces and by the constant movement of steamers, there has been obtained a depth of about 19½ feet, or 21½ feet at mean high tide. Opposite Farallon, a rocky point on the Uruguay shore and opposite Buenos Ayres, there is, along the course of navigation, about 19½ feet at low water. The Government has buoyed with luminous buoys the entire route from Buenos Ayres to the mouths of the Paraná River, the Bravo and the Guazú, and has placed a floating semaphore below Martin Garcia for the benefit of navigation, recording constantly by signals by day and by night the depth of water in the channel. It is now proposing to connect this semaphore by a telephone cable with the telegraph cable of Martin Garcia, so that communication may be established between the ships lying at anchor (waiting for the tide) or passing near the semaphore, with the offices of the agents at Buenos Ayres or Montevideo.

A careful study of the different conditions in the delta of the La Plata shows that the only method of improvement in such a vast expanse of water is by dredging and buoying the best channels.

In the lower Rio de la Plata there are very serious conditions. A bar on which there is a least depth of 20 feet at low tide lies between the anchorage of Buenos Ayres and Montevideo; the material in this bar is very soft and vessels plow their way through it at ordinary tides; but the great extent of the bar is the serious condition. Between the 24 feet curves, straight through this bar, there is a distance of 24 sea miles. To make a channel by dredging would require the removal of probably from 10,500,000 to 13,000,000 cubic yards; and it is very doubtful if, on such a broad extension of water and in such soft material, a channel could be maintained. But it is hoped that the plan now proposed of anchoring five lightships in the line of navigation, and in the direction of the current, and which can be seen from each other, will have an effect upon the bar by the continual movement of deep steamers through

it. The examination of the Rio de la Plata Inferior has been intrusted by the Government to the Ministry of Marine, which is making very extensive surveys and examinations over the entire area.

The estuary at this point is 46 miles wide, and five high towers on shore and others anchored within the area to be surveyed are necessary in order to cover this great Punta Indio bank.

These are the general physical conditions of the Rio de la Plata and its great tributaries.

The very important project of making a deeper channel of access to the Port of Buenos Ayres and enlarging the port to give it not only greater area and more facilities but greater depth in the enlarged part, is now before the Government, and the plans for it (made by myself) have been approved. There are alternative projects to meet the commercial necessities of the country: one is to deepen the present Port of La Plata and endow it with more facilities, where vessels drawing 24 or 25 feet may come in and go out at any stage of the tide; or to build a deep water port with a depth of not less than 30 feet on the seaboard outside of the difficult conditions of the Rio de la Plata. A concession has been granted and the project submitted to the National Government for an artificial port in the Great Bay of Samborombon, which is almost opposite Montevideo, and another concession for a port at Mar Chiquita, near Mar del Plata on the ocean, has also been granted.

In addition to the great drainage basin of the La Plata, there is farther south the large rivers, Rio Negro and Colorado, which, combined, have a drainage area of 464,000 square miles. The channels are not susceptible of improvement for a large commerce, but they will in the future furnish water for an extensive irrigation and steamboat navigation.

The hydraulic conditions are great, but the mountains are greater, and have exerted a powerful influence on the continent, not only its climate and its running waters but upon mankind. On these lofty table-lands lived the Incas and flourished their great empires. Among the clouds have

fought for supremacy the Incas troops and the Spanish soldiers, and here, too, have the struggles for liberty taken place; here Bolivar and San Martin led their troops to victory and continental freedom from the domination of Spain.

An orographic map of South America will show what immense areas are given up to mountain ranges and lofty summits. In their widest part the Andes are 500 miles in breadth. Some mighty force seems to have pushed them and the entire continental line eastward and massed the ranges into a complex system of mountains, towering isolated peaks, and parallel, transverse and interlaced ridges without number. In Bolivia, not far north of the country we are describing, there are thirty-two peaks above 17,000 feet high, some of them reaching over 21,000 feet; and in Argentine is the lofty Aconcagua lifting its solitary crown to an elevation of 23,080 feet, rivaling the loftiest mountains of the world. And Famatina, in the Argentine Province of Rioja, rises to 20,680 feet, and the grand mountain Tupungato 22,015 feet high.

Between Argentine and Chili, between latitude 23° and 35°, the mountain passes, which are from 10,000 to 14,000 feet high, are blocked with snow from May to August, and they are swept by violent storms.

The height of the passes, all the way from 7° to 37° south latitude, Northern Peru to Southern Argentine, shows the determination of Nature to oppose transit by man, piling up in his pathway these almost insurmountable obstacles. When it is considered that this immense barrier covers a sixth part of the circumference of the globe, its influence upon the development of the continent is apparent. The general condition, so far as civilization is concerned, and the obstacles in the way of mankind are forcibly and most interestingly described by Colonel Church, comparing them with the conditions in North America:

"The contrast between North and South America is remarkable. Nature was in her kindest mood when she created the former—gave it vast and fertile plains; low and readily transitable mountain ranges; extensive systems of navigable lakes and rivers—the latter not too difficult to

bridge; great forests of the most abundant timber; immense mineral wealth, including an abundance of coal and iron; a coast-line offering numerous excellent harbors easily accessible from the interior, and a temperate, inviting climate over almost its whole area. It is a land where man seems to live with Nature on friendly terms, and where the wave of humanity, as it rolls westward, encounters no obstacle which it cannot readily overcome.

"How opposite to all this is South America! It lies mostly within the tropics. Its fertile plains, except those of the Argentine Republic, are difficult of access; it is a formidable task to scale and cross its mountain ranges. Its rivers, with rare exceptions, are of violent flow and full of obstacles to navigation, and its largest ones not within the limit of practical engineering to bridge. Its vast forests are hard to work and frequently impenetrable. Its mineral wealth, immense in nobler metals, includes but little coal and iron. Its coast has but few good harbors, and these are almost all mountain-locked. Its climate, although in many parts delightful, is uninviting over extensive regions. The forces of Nature are so vigorous that man can seldom count upon the unqualified control of them, and, in general, they confer generous reward only upon well-applied and persistent energy."

The above is an introduction to his very important paper read before the Royal Geographical Society, February 25, 1901, entitled "South America: An Outline of Its Physical Geography," a paper of seventy-four printed pages. His conclusions are as follows:

"My analysis shows that, in general, man finds himself confronted by severe conditions in his struggle with Nature in South America. Thus far, however, his efforts to develop and utilize its vast resources have made its commercial history an epic. The thought naturally presents itself: that had North America fallen to the lot of the Latin race in the European occupation of the New World, and South America to the Anglo-Saxon, the former might still have maintained its supremacy; for the more rapid progress of the former may not be due so much to racial superiority as to advantageous geographical surroundings."

Having outlined the physical conditions and shown their importance and influence, let us review very briefly the history of man among these extraordinary physical features of a great continent.

Mountains and streams and soils, and nature in general, are always of interest; but man—his history, his ethnology, anthropology and biography are of still greater interest to us, especially when human life and character have impressed themselves upon the country in which we are immediately interested.

I am tempted strongly to take you on an excursion in the wide field of American ethnology and examine the races and tribes that were found by our first ancestors when they came and began the development of both North and South America, but time compels me to limit myself to an allusion only; for a volume would be required to take up the subject of the savage tribes alone of America—450 principal groups, and 2,000 if we separate them by dialects. And another volume would be needed to treat of the civilized aborigines of the table-lands of Mexico and Peru; of the Toltecs and Aztecs and of Quetzalcoatl and the Incas; the pontifices, who ruled over a vast population covering 40° of latitude of South America, from Northern Argentine to the Antilles. The barbarism of the savage and the civilization of the races of the table-lands have nearly disappeared. You would have no better knowledge of that vast horde of wandering tribes that infested the great plains of the Pampas if I should mention their names. Some few still exist; the census gives less than 20,000 as the total of Indians still existing in Argentine. Once numerous and brave, only about a dozen remain of the Paraguas, the descendants of the Aguas; and of the Tobas and Chinipis, who later occupied their country, a remnant only exists. From the photograph you may judge of their present character.

It is unnecessary to go into the history and the influence of the Incas; they have been described in the histories to be found in every library of the land. But it may not be generally known that, from the first arrival of the Spanish adventurers to the successful end of the great struggle for

liberty in South America, there was always dissatisfaction, unrest and hatred of the conquering race. The seeds were sown in bloodshed, in the persecution by the Inquisition and in false commercial and governing methods of Spain and Portugal, the mother countries. The difference between North and South America in this respect was very great.

The symptoms of resistance against Spanish domination showed themselves in the dawn of the history of South America. Frequently the Indian tribes attempted to throw off the yoke of some more than usually severe and cruel oppressor. In the early days of the eighteenth century the revolution of Tupac-Amaré was really a war of races rather than a political revolution, as it had for its principal purpose the extermination of the Spanish. In Venezuela, in 1711, this same hatred showed itself in the proclamation of a mulatto as King of the Mestizos. Half a century later the seed sown by Antequera bore fruit in New Granada, when an army of 20,000 men was raised and commanded by Berber.

It is a significant and curious fact in the history of South America that, during the entire eighteenth century, the same causes were producing the same effects among people far separated from each other and of a character entirely distinct, scattered from the banks of the Paraguay River to the Colombian Mountains.

Those effects may have been the precursors of that great revolutionary movement that created our great republic and drove the Bourbons from the throne of France, and, later, shook to the center the monarchical fabric of Spain herself.

We may therefore say that the struggle and the preparation of the ground for civil and religious liberty began earlier in South America than in North America. In the British Colonies there was no strong sentiment against foreign rule until the imposition of the taxes required to furnish George III with revenue to pay off his debt of £148,000,000 sterling. Even Washington, in July, 1775, when he took command of the Continental Army, declared that the idea of independence was repugnant to him. Only

later, and soon, when the war was suddenly upon the Colonies, did events hasten and make inevitable the separation from the mother country.

It would be a subject of great interest to enter upon—the three great leaders and heroes of American revolutions—

WASHINGTON, BOLIVAR, SAN MARTIN—

a triumvirate of liberators.

Of the former two you already know much, possibly of the latter; but you may not know that it was by his patriotism and generalship that the whole of Southern South America was freed from the yoke of Spain—Argentina, Chili, Peru and Bolivia. His biography is a romance of most absorbing interest.

Born 1778 in Argentine, in Japeyú; his early education in Buenos Ayres, completed in Spain; served with distinction and great bravery in the wars of Spain. Early he was imbued with the doctrine of liberty for his native country; spent a year in Great Britain, in 1811, forming associations and a secret league devoted to the liberation of Argentine. Landed in Buenos Ayres in 1812; soon in command of a regiment of grenadiers; selected soldier by soldier, officer by officer; imposed the most rigid discipline, forming so a rudimental school for a generation of heroes that followed him, and produced nineteen generals and nearly all the great men of the struggle for independence; placed in command of the army to reorganize it; marched to Mendoza, the nearest point to the Andes; and, imbued with the idea that no liberty would be secure for his country until the Spanish armies were beaten and expelled from Chili, Peru and Bolivia and the whole of South America, he formed his plans for an invasion of Chili. He was the very incarnation of determined patriotism; nothing, not even revolutions and discords behind him in his own country, could deter him from his great work. At this moment Napoleon fell, and Spain prepared an expedition of 15,000 men destined for the Rio de la Plata. In Chili and Peru the Royalists were victorious; but in Argentine, on the 9th of July, 1816, at Tucuman, the declaration of independence was pro-

claimed, which, like our own, is sacred in the heart of every Argentine.

In the midst of these great and momentous events, San Martin recruited and drilled and clothed and provisioned his little army destined to conquer a continent, to scale high mountain passes and pour down upon an enemy largely outnumbering his own. His plans were known only to himself, and when asked by those high in authority what they were, he refused to tell and said *no* one should know them; and should his pillow get an idea of his plans he would cast it into the deep. He ostensibly made roads over certain passes and, when all was ready, led his army over another and very different pass and came down upon his foe and defeated him in Chacabuco; and again, on the plains of Maipú, routing the enemy completely and assuring the independence of Chili. Then, though anarchy was reigning in Argentine and his Government was calling upon him to return, his fixed and irresistible purpose of dealing the final blow to Spanish authority in Peru pushed him forward. With a fleet hastily gotten together and commanded by Lord Cochrane, and with English and U. S. officers in command of the ships, he sailed from Valparaiso with his troops up the coast in December, 1818. He had only 4,430 men, Agentines and Chileans. The Viceroy of Peru had 23,000 soldiers awaiting this little army. On July 28, 1821, as a result of his campaign, the independence of Peru was proclaimed in Lima and San Martin made dictator. In the meantime General Bolivar, after liberating Venezuela and Colombia, reached Quito, and his forces united with an Argentine division, routed the Spanish army in the battle of Pichincha; and then he hastened on to Guayaquil, anxious to finish by himself the Peruvian campaign. Here let me quote a paragraph from the history of Argentine by the Hon. Martin Garcia Mérou, the Argentine Minister at Washington:

"There he went to find San Martin, whose purity of character and noble unselfishness formed a marked contrast with the impetuous ambitions of his glorious rival. The two liberators had a conference July 26, 1822, the details of

which were kept secret; but it is a well-known fact that San Martin comprehended that, in order to save South American independence and avoid the scandal to the world of a break with Bolivar, caused by the latter's thirst for glory, it would be best for him to depart from a scene where his great presence had no place."

The story of self-abnegation and the rest of his life is told in a word. He resigned the dictatorship of Peru; passed to Chili, to Mendoza, to Buenos Ayres, to Europe, where he resided four years in Brussels on a very modest pension. Once more, in 1829, he returned to the La Plata, landing at Montevideo, but learning that anarchy prevailed in his own country and deaf to the entreaties of his friends to come to their help, he took a steamer back to Europe, saying: "No; General San Martin will never spill the blood of his fellow citizens; he will draw the sword only against the enemies of America." And, without even seeing Buenos Ayres, he sailed for the last time to his voluntary exile, dying suddenly August 19, 1850. He was free from those theatrical qualities which appeal to the multitude. In his great character predominated those moral qualities which entitle San Martin to a prominent place in South American history. Inflexible in the discharge of duty, a rigid disciplinarian, everything was subordinated to the high mission to which he had devoted himself, and he never sacrificed his cause to ambitious or personal vainglory. *He was the incarnation of an idea.* His modesty, his pure and elevated character, the simplicity of his life and the nobility of his principles give him rightfully a position by the side of the great heroes of history.

In the vicissitudes of the epoch under consideration, when European wars and the disasters of nations reflected themselves directly and indirectly upon the people of the River Plata and led slowly to the formation of the Republics of Uruguay, Argentine and Paraguay, many notable and great men, as well as despots and bloody tyrants and political demagogues, appeared upon the scene and the pages of history. No name more illustrious, contemporaneous with San Martin, is seen in the records of that time

more brilliant and more important in results than that of General Belgrano. His generalship, diplomacy, statesmanship and exalted patriotism give him a most distinguished position in the annals of independence As General Mitre has well said in the opening sentence of his history of Belgrano: "This book is at the same time the biography of a man and the history of an epoch." His statue is before us as we stand in the archway of the National Government Building and look out upon the beautiful Plaza Victoria. General Belgrano was really the author of the national flag. The white and the blue are the colors of the uniform of the Patricios, the regiment of native Americans at the time of the overthrow of the Spanish Viceroy, on the 25th of May, 1810.

[*To be continued.*]

Notes and Comments.

ALUMINIUM ALLOYS.

Among the aluminium alloys recently placed on the market, two have especially occupied the attention of metallurgists in a prominent way—namely, "magnalium" and "meteorit"—two German inventions. A report on the properties of these alloys has recently been published by a German contemporary, from which we take the liberty to quote the following description:

About ten years ago Dr. Ludwig Mach experimented with alloys for the production of metal mirrors. It was considered indispensable that the composition aimed at should be light, hard, tough and susceptible of polish, and that its gloss should not be easily affected by the air. An equal mixture of magnesium and aluminium proved a very suitable alloy. Following up this discovery Dr. Mach systematically tried all possible proportions of magnesium and aluminium according to their properties and technical adaptability, giving the most approved one the name of magnalium, on the production of which he has obtained patent rights from the Imperial Patent Office at Berlin. Before this, various experiments had been made, with a view to the discovery of suitable alloys, but as at that time neither of the two metals could be obtained technically pure, the alloys did not possess the valuable properties which distinguish the new magnalium.

Aluminium, as well as magnesium, is most difficult to work, inasmuch as the former chokes up the file and is liable to break, while the latter is so tough that neither a file nor the turner's chisel can make any impression. Magnalium, on the other hand, is more suitable than either of its component parts. Alloys containing up to 30 per cent. of magnesium, furnish a metal the hardness of which lies about half way between yellow and red brass, and

which may be easily worked with any tool; even the weakest screw-threads can be cut with proper keenness. The chips are like those of yellow brass, the faces of the pieces are smooth and bright, and choking never takes place even with the finest files. Magnalium, moreover, is chemically less assailable than either of its components. Aluminium by itself has a very indifferent exterior, while magnesium by itself is greatly affected by the air, and oxidation will gradually extend far into the interior. Magnalium is silvery white, remains unaffected by exposure to the air, nor can ammonia or acetic or sulphuric acid harm it in any way. It surpasses aluminium in gloss, tractability, firmness and lightness.

The combinations of aluminium with copper or with zinc can easily be made, but as these two metals are a great deal heavier than aluminium, all the advantages due to the light weight of the latter are lost. While aluminium has a specific weight of 2·7, the alloys referred to range betwe n 3 and 3·5. A notable contrast to this is presented by the specific weight of magnalium, which is less than that of pure aluminium—namely, 2 to 2·5—according to composition. Magnalium produced in Sweden shows a specific gravity of only 2·4 to 2·7.

Magnalium is sold in the form of bars, tubes, sheets and wire. For melting purposes, crucibles of graphite or of iron are used, the inside of the latter having been lined with clay and magnesia. Molten magnalium can be poured into the thinnest vessels of a diameter of down to 2 millimeters and of the most intricate forms, and will fill them up thoroughly and faultlessly. It becomes soft at 570°, melts at 600° and becomes fluid at 630° C. On account of its lightness and its silvery white color it is in a high degree suitable for metallic mountings on photographic apparatus, optical instruments and similar articles.

Unfortunately, sea-water is inimical to magnalium, especially when the latter comes in contact with other metals. This defect renders it, of course, impossible to use the new alloy for ships, as desirable as this might be, on account of its lightness and eminent solidity, especially for men of war.

In cases in which, for technical purposes, great solidity is of paramount importance, as, for instance, in regard to large castings, an alloy of from 3 to 5 per cent. of magnesium is most suitable. An addition of 10 per cent. of magnesium would render magnalium brittle, while 30 per cent. of magnesium would reduce the solidity of the alloy still more. With only 2·4 per cent. of magnesium added, magnalium can be forged at a temperature of 400° C., and will then act in a similar way to copper at red heat. If containing less than 5 per cent. of magnesium, it may be forged in the cold state, and if perchance the hammering has rendered it too hard, it can be made malleable again by heating to a temperature of 500° C. and chilling it thereupon in cold water.

The price of magnalium is about the same as that of copper, and depends mainly upon the price of magnesium. Whereas, aluminium may be had (in Germany) for 2 marks (48 cents) a kilogram, the price of magnesium is kept up steadily at 20 marks a kilogram. Were it not for the high value of the latter metal, the price of magnalium would be considerably lower than that of copper. It is, however, to be expected that the growing demand will lead to an increased production of magnesium, with the result that also this metal will come down much like aluminium, which, as is well known, has expe-

rienced an extraordinary reduction within the last few years. The cheapening of magnesium, however, will be the forerunner of more moderate prices for magnalium.

It remains to be seen whether magnalium will fulfil all the promises given above. Our report states in a general way that aluminium-magnesium alloys also show when worked the great defects of mechanical mixture, as hard places frequently occur in the work. If the tool comes in contact with such hard places it frequently breaks, or the material breaks away, whereby the work done may be considered as practically lost.

ODD USES FOR RAWHIDE.

It was the great packing and killing houses of Chicago which helped to bring about the present uses of rawhide, says the New York *Sun*.

Rawhide is a form of leather in which the curing process stops far short of destroying the life of the material. The result of this treatment is a product remarkable for toughness, durability, tensile strength and pliancy. It is used for belting, rope, hydraulic packing, laces of various kinds, pinion-wheels, washers, harness, mauls and mallets, flynets, trunks, saddles and artificial limbs.

Rawhide rope is handsome and astonishingly strong, besides having great power of resistance when exposed to the action of the weather. At a little distance it looks like very white and clean new hempen rope. It is delightfully supple, and once tied it holds for a lifetime. The cost of such rope puts it beyond the reach of most consumers, yet for some purposes it is the cheapest material that can be used.

It costs from 10 or 12 cents to more than $2.75 a foot, according to diameter and quality. The cheapest is about ¼ of an inch in diameter; the most expensive, save that made to order in special sizes, is 2¼ inches in diameter. It is largely used for the transmission of power, especially where the line of transmission is long and indirect. Only a close examination brings to light the points where strands are joined, and splicings are so made that they show no change in the diameter of the rope.

One of the most curious applications of rawhide is to the manufacture of pinion-wheels for the transmission of power. Such wheels are usually made of iron or steel, but the rawhide can be made sufficiently rigid, hard and tough to serve all the purposes of metal in such articles. The rawhide pinions are almost noiseless, and they require little lubrication. A somewhat similar use is in the gear of friction wheels.

Mallets and mauls of rawhide are used for a variety of purposes in manufacturing. The former are entirely of hide save the handle; the latter have a wooden or metallic base with a rawhide face. Hammers with rawhide faces are also made.

The old-fashioned rawhide whips, the "cowhide" of many a social and political row, are made in several forms, as are blacksnake whips of the same material, rawhide lashes, and miners' whips. Rawhide lariats are also manufactured, though there was a time when every plainsman made his own. They cost from 15 to 20 cents a foot, according to diameter and form of pleat. They are rarely seen east of the Mississippi save in the factories.

Book Notices.

Worm and Spiral Gearing. By Frederick A. Halsey, Associate Editor *Am. Machinist*. 12 mo. pp. 85 New York: D. Van Nostrand Company. 1902. (Price, 50 cents.)

This volume forms one of the well-known "Van Nostrand Science Series" and is substantially a republication from the *American Machinist*. The author refers to the prevalent opinion among designers of machinery that worm-gearing is necessarily short-lived and of low efficiency, and to the circumstance that the methods of laying out spiral gearing are not generally understood, as his justification for publishing his work in book-form.

The work is divided into two parts: (1) devoted to worm-gearing, and (2) to spiral gearing. In Part I, the theory of worm-efficiency and its experimental corroboration are treated of, with examples from practice.

In Part II, spiral gears are compared with spur gears, and both analytical and graphical methods of laying out are given. The work is illustrated by a number of plates. W.

Electro-Chemical Analysis. By Edgar F. Smith, Professor of Chemistry, University of Pennsylvania. Third edition, revised and enlarged, with 39 illustrations. 8vo, pp. 203. P. Blakiston's Son & Co., Philadelphia. 1902. (Price, $1.50.)

Profes-or Smith's numerous contributions to the application of the electro-chemical method to the quantitative determination of metals and analytical operations are widely known His present work, though entitled a third edition of his "Electro-Chemical Analysis," is practically a new book, having been substantially re-written. An interesting and useful feature is the introduction of a description of the proper equipment of an electro-chemical laboratory. In the special portion of the book, the methods of separation have been thoroughly revised. Quite a number of new illustrations have been introduced. W.

Die Gewinnung des Aluminiums und dessen Bedeutung für Handel und Industrie, von Adolph Minet. Ins Deutsche übertragen von Dr. Emil Abel (Mit 57 Figuren und 15 Tabellen im text). Large 8vo, pp. vii + 129. Halle a. S. Verlag von Wilhelm Knapp. 1902. (Price, 7 marks.)

Die Darstellung des Chroms und seiner Verbindungen mit Hilfe des elektrischen Stromes. Von Dr. Max Le Blanc. Large 8vo, pp. 108. Halle a. S. Verlag von Wilhelm Knapp. 1902. (Price, 6 marks.)

The publications relating to electro-chemistry and electro-metallurgy now appearing from the press of above-named publishing house, promise to make an extremely valuable set of contributions to the literature of these important and rapidly growing branches of the electrical arts.

The volumes above entitled are respectively No. II and No. III of a series of special monographs on applied electrochemistry—one dealing with the aluminium industry and the other with chrome and its compounds. W.

The Elements of Electrical Engineering. A first year's course for students. By Tyson Sewell, A. I. E. E., etc. 8vo, pp. x + 332. New York: D. Van Nostrand Company. London: Crosby Lockwood & Son. 1902. (Price, $3.00.)

This work is based upon courses of lectures given by the author to classes of students intending to qualify as electrical engineers. The author has avoided, as far as possible, the mathematical treatment of his subject, which will doubtless commend it to those who are not sufficiently conversant with mathematics to utilize it.

A useful feature of the book is the introduction, with each topic treated, of problems, in the form of questions and answers, which cannot fail to prove very serviceable to the student. The work answers its intended purpose very satisfactorily. W.

Einführung in die Elektrochemie. Nach der elektrolytischen Dissociationstheorie bearbeitet von Peter Gerdes. Mit 48 in den Text gedruckten Abbildungen. 8vo, pp. viii + 223. Halle a. S. Druck und Verlag von Wilhelm Knapp. 1902. (Price, 4 marks.)

This work, as its name indicates, is an introduction to electrochemistry, and is intended to serve as a guide in the preliminary study of the fundamentals of the science. The various chapters are devoted to fundamental conceptions, osmosis and osmotic pressure, electrolysis, polarization, acids, bases, salts, etc., electrical-current generation, decompositions by the electrical current, electrolytic laws, tables, etc. W.

A Text Book of Quantitative Chemical Analysis. By Frank Julian. 600 pages, octavo, illustrated. First edition. St. Paul, Minn. The Ramsey Publishing Company, 1902. (Price, $6.00.)

This work treats of the subject in four parts. I. An introductory chapter dealing with tests, methods and general principles of chemical analysis; II, of reagents; III, of special methods and technical analysis; IV, notes on the methods of analysis, and an Appendix. W.

The Art of Illumination. By Louis Bell, Ph.D. 8vo, pp. 339, 127 illustrations. New York: McGraw Publishing Company, 1902. (Price, $2.50.)

This work deals directly with the scientific and artistic use of modern illuminants. The first three chapters are devoted to a discussion of the physical and physiological principles which form the basis of the art of artificial lighting. Then in succession are taken up the properties of practical illuminants and their bearing upon the development of modern lighting. The chapters upon electric incandescent lamps and arc lamps are especially rich in practical information regarding their economical and artistic use. The following chapter (VIII) on shades and reflectors contains a mass of data on this neglected topic which would require a long search to duplicate. Then the lighting of the house, of large buildings and of streets, is treated in successive chapters, and concrete cases illustrative of the principles laid down are worked out in detail. A separate short chapter is devoted to the basic principles of decorative illumination for special purposes, and then the line

of progress in the effective and economical use of the materials at hand is marked plainly out. The volume closes with a clear setting forth of the methods and apparatus employed in modern photometry. W.

A Graphic Method for Solving Certain Questions in Arithmetic or Algebra. By George L. Vose. Second edition. 12mo, pp. 62. New York: D. Van Nostrand Company, 1902. (Price, 50 cents.)

This volume is devoted to the extension of the applications of the graphical method to the solution of many problems in arithmetic and algebra, which may be new to many who are familiar with the system in its general applications. W.

Metallurgical Laboratory Notes. By Henry M. Howe, Professor of Metallurgy in Columbia University, New York. Boston: Boston Testing Laboratories, 1902. 8vo, pp. xiv+140. (Price, $2.50.)

The laboratory notes on metallurgy embraced in the work above named will be found extremely serviceable by students of this branch of applied science. The progress made in this field of late years has been most notable, and the author of these notes has contributed substantially to its development. The experiments described embraces (1) squad experiments and others for a short course in metallurgy; (2) pyrometry and calorimetry; (3) melting points of silicates, etc.; (4) properties of refractory materials; (5) iron and steel; (6) non-ferrous metals; (7) appendices, notices, etc. W.

Franklin Institute.

[*Proceedings of the Annual Meeting held Wednesday, February 18, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 18, 1903.

President JOHN BIRKINBINE in the chair.

Present, 37 members and visitors.

Additions to membership since last report, 17.

Two donations of $1,000 and $5,000, respectively, were reported from the Board of Managers, the donors, in each case, desiring their names to be withheld from publicity.

The action of the Managers in accepting these gifts with the thanks of the Institute was approved.

Mr. G. Everett Hill, of New York, presented a paper on "The Bacterial Disposal of Sewage." The paper was illustrated by numerous lantern-slides, and was listened to with great interest. On the conclusion of the paper considerable discussion followed, many inquiries from members being made for information on points respecting the construction of plants, etc.

The paper will appear in the *Journal*.

Adjourned.

H. L. HEYL,
Secretary pro tem.